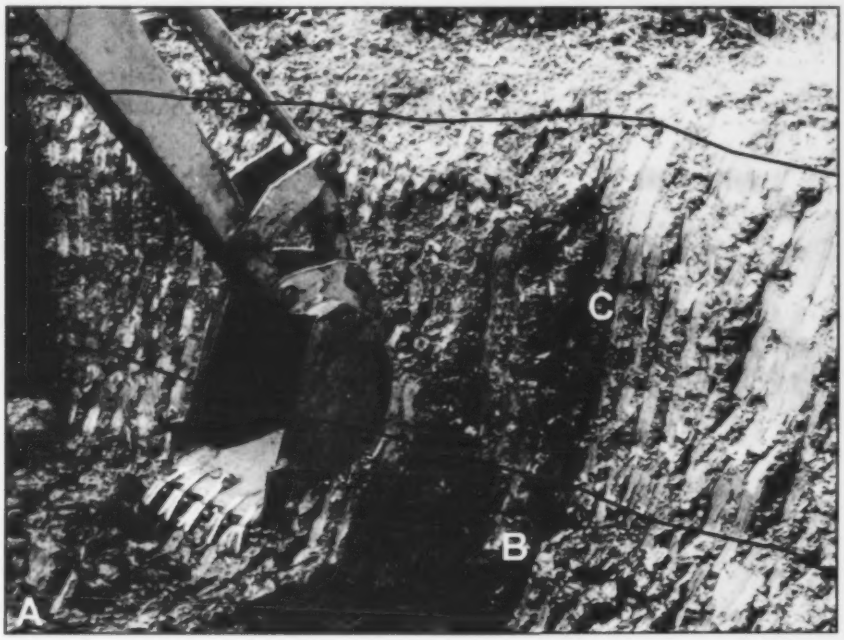
MINERAL RESOURCES BRANCH

GEOLOGY AND ECONOMIC POTENTIAL OF THE GLACIAL CLAY AND SAND DEPOSITS OF INVERNESS COUNTY, SOUTHWEST CAPE BRETON ISLAND



ECONOMIC GEOLOGY SERIES ME 2006-1

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Honourable Brooke D. Taylor
Minister

Peter Underwood
Deputy Minister

Halifax, Nova Scotia
2006

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Cover photo. Backhoe excavation of a clay deposit at site 55/00 in the Moran basin (Map 1). A: clay with silt and sand beds. B: massive silty clay. C: blocky, silty clay with rootlets. D: soil horizon.

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Geology and Economic Potential of the Glacial Clay and Sand Deposits of Inverness County, Southwest Cape Breton Island

R. R. Stea[2], M. Feetham[2], S. E. Pullan[3], W. Ostrom[4], L. Baechler[5] and R. J. Ryan[2]

Summary

Large glacial lakes formed in southwestern Cape Breton Island at the end of the last ice age when glaciers dammed meltwater outlets into the Gulf of St. Lawrence and the Atlantic Ocean. These lakes occupied lowland basins and were filled with fine-grained, turbid sediment from eroding till deposits washed in by slope runoff and glacier melt in the highlands. The sediments settled and formed clay and sand deposits with the potential for use as pottery and structural ceramic products, landfill liners and cover caps, aggregates, and as sources of potable water. Clay deposits found in these basins are unusually fine-grained and massive, lacking the graded beds with coarse silt and sand that often characterize glacial lake sediments (varves) and exhibiting a low percentage of dropstones. Sand and gravel deposits often formed on the margins of the glacial lakes (outwash) and on slopes between melting lowland and highland glaciers (kame terraces).

Mapping and sampling in the Moran basin near Glencoe revealed clay deposits that are widespread, fine grained and massive. Use of clay as a resource material for pottery and structural products depends on a range of properties unique for each industry. A common denominator for industrial uses is a large-volume source of moderately uniform clay that has a low shrinkage/swelling percentage, consistent firing colour, relatively low firing temperature, and good strength after firing. The Moran clay is of the earthenware type, and meets the requirements of many low temperature ceramic products. It has an extremely low firing temperature, excellent strength, low boil absorption and low alkali content, and may be suitable for structural products (brick and tile), provided it is mixed with a suitable filler to reduce the dry shrinkage, lamination tendency and demand for water of extrusion.

The Moran clay is also suitable for pottery and artware. It is excellent for throwing, does not scum or effloresce when fired, and accepts a variety of glazes. A disadvantage of these deposits is a content of tiny stones that create some imperfections and cracks in the final product when not detected on the potter's wheel. The high plasticity may require some filler or grog for larger pieces or sculptural work to reduce shrinkage and facilitate drying.

Sand and gravel deposits of varied quality for use as aggregates can be found in Inverness County, primarily in kame deposits on the margins of the highland blocks, dominated by harder, older rocks.

Artesian gravel and sand aquifers are present in the lowland basins, confined between glacial tills and clay deposits. The water quality is poor in the Kingsville area due to the proximity of salt deposits, but buried surficial aquifers in other lowland areas may provide high yields of potable water in areas underlain by poor bedrock aquifers.

Introduction

This report describes the nature, distribution, origin and economic potential of clay and sand deposits found in Inverness County, southwest Cape Breton Island (Fig. 1). These deposits are of sedimentary origin and Quaternary age, deposited by glaciers as

[1]Funded by Natural Resources Canada and the Nova Scotia Department of Natural Resources under the Targeted Geoscience Initiative (Phase 1) project: Geological Mapping for Mineral Development in South-central Cape Breton Island

[2]Nova Scotia Department of Natural Resources, PO Box 698, Halifax, Nova Scotia B3J 2T9
[3]Terrain Sciences Division, Geological Survey of Canada, Ottawa, Ontario
[4]Nova Scotia College of Art and Design, Halifax, Nova Scotia
[5]ADI Limited, Sydney, Nova Scotia

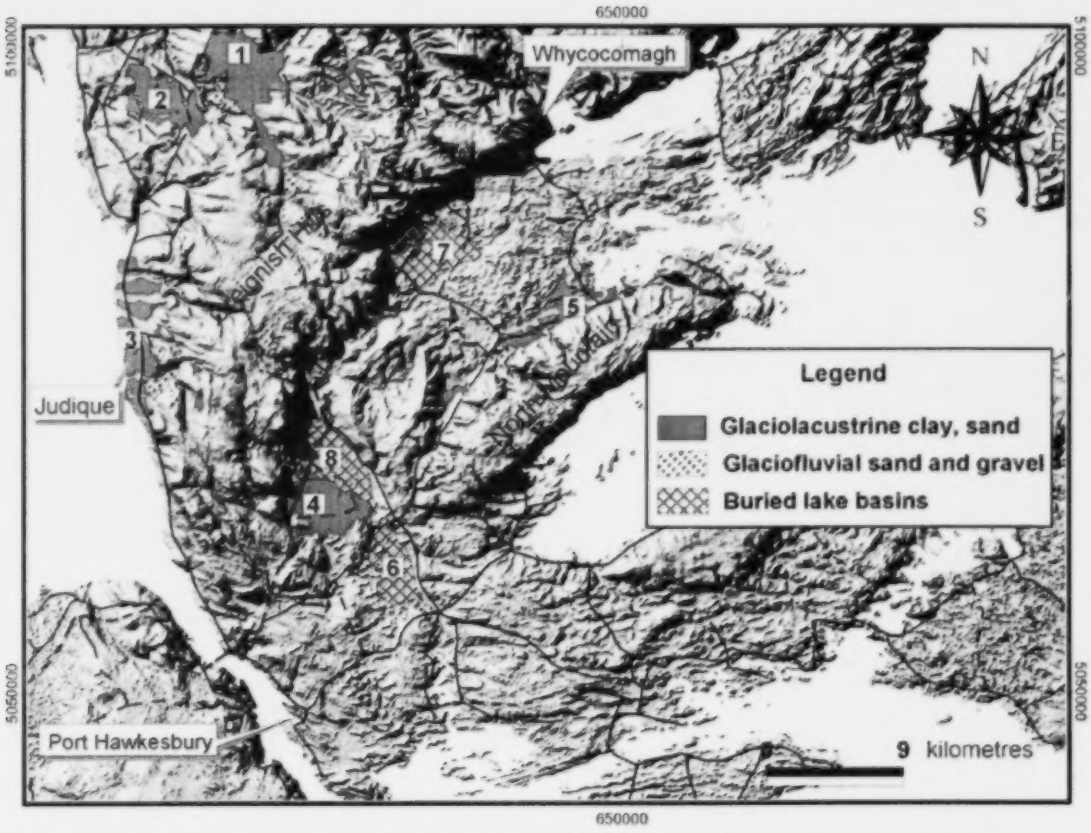
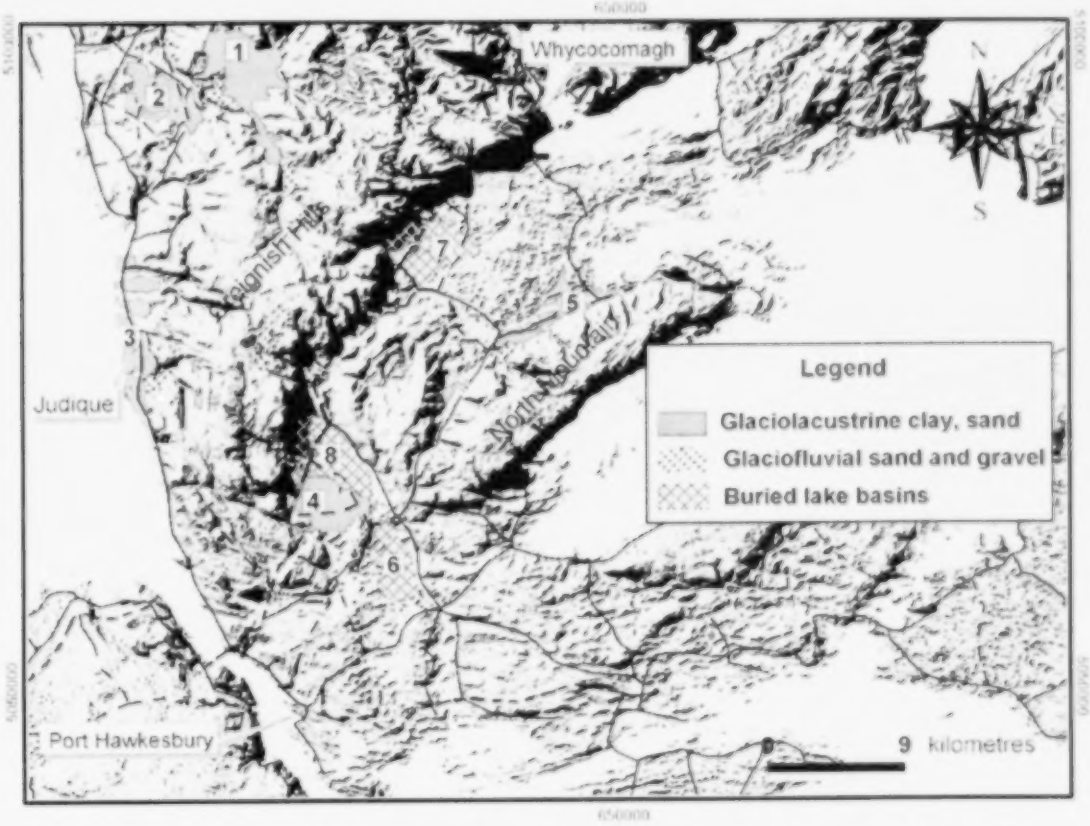


Figure 1. Location of glaciofluvial and glaciolacustrine basins in Inverness County, Cape Breton Island. Surface deposits: 1. Moran basin, 2. Hawthorne basin, 3. Judique coastal plain, 4. Queensville area, 5. River Denys basin, 6. River Inhabitants lowland. Buried deposits: 7. Big Marsh lowland, 8. River Inhabitants lowland (coordinates in UTM NAD 27).

they developed, advanced and retreated over the area between 75,000 and 15,000 years ago. The greatest quantities of these economically important sediments were deposited in large glacial lakes that formed when the great ice sheets receded. Included in this report are comprehensive data on the geology of the clay deposits and the properties of the clay and sand deposits that render them useful for ceramics, landfill liners and cover caps, aggregates, and as sources of potable water.

The report focuses on the geology of Quaternary clay and sand deposits in the lowland regions of Inverness County, providing a three-dimensional view of glacial sediments and the underlying bedrock topography. Knowledge of the basin architecture can aid in the delineation of buried clay and sand deposits of potential economic value, in the search for groundwater resources and their management and protection, and in determining the suitability of areas for construction and development.

Before this survey, only a few Quaternary clay occurrences of economic value had been described in Inverness County. Ries and Keele (1911), in their comprehensive review of ceramic clays in the Maritime Provinces, described a local clay deposit near Eden Siding used to make brick in the early part of the Twentieth Century. The clay deposit was mined by the Miller Brothers and provided bricks for the Sydney Steel Plant and the Roman Catholic church in Iona. Gouthro (1989) provided additional ceramic data for clay deposits in the



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vicinity of Eden Siding. Shea and Wallace (1962) described a deposit of "fireclay" discovered through auger borings under gravel near Queensville, which was probably Quaternary clay similar to the clay that will be described in this report.

Glacial sand and gravel deposits throughout Inverness County are being used for fill at construction sites, as a base for roads, and many other uses. During the course of this study many sites that have aggregate potential have been documented.

The initial results of Quaternary mapping and sampling of sand and clay deposits during the project have been published in Stea *et al.* (2002, 2003) and Stea and Feetham (2003). This report will summarize those previous findings with additional geological data and comprehensive ceramic testing results. Also included with this report are two full colour surficial geology maps with comprehensive marginal notes, denoted as Map 1 (NTS 11F/14-Whycocomagh area) and Map 2 (NTS 11F/11-Port Hawkesbury area).

The project was part of the Targeted Geoscience Initiative, Phase 1 (TGI-1), a project jointly funded by Natural Resources Canada and the Nova Scotia Department of Natural Resources. The initiative was carried out to stimulate mineral resource development in Cape Breton Island.

Survey Methods

The techniques used to find and delineate clay deposits include field mapping, backhoe excavations, shallow seismic surveys, and rotary and auger drilling. Field mapping involves:

1. Road, stream and coastline traverses to describe and classify the various types of surficial deposits. Cores are recovered to depths of 3 m with an Edelman auger for stratigraphic information.
2. Air photograph interpretation and ground verification to delineate the areal extent of units by matching the surficial deposits (clay, till, sand, colluvium) with identifiable landforms, vegetation and drainage patterns, and human activities (e.g. pits and quarries).
3. Input into a GIS (ArcView®) platform and integration with other data sources (previous maps, well log data, etc.) for final map production. Soil maps by Cann *et al.* (1963) and a regional surficial map by Grant (1994) were used as base information to be built upon in this study. Many of the regions where clay deposits were found were previously mapped as clay-rich till.

Seismic Surveys

The shallow seismic reflection survey in this study involved both a testing phase and a production phase. The seismic testing program was designed to obtain an estimate of the depth to bedrock at each site, and ideally, some information on the surficial stratigraphy at sites where drift thickness exceeds 30 m. The methods are fully described in Pullan and Hunter (1999). At each site in this study area, data were acquired using an array of 24 geophones (Mark Products 50 Hz in marsh cases) at 3 m spacings (active spread length = 70 m), generally deployed along roadside ditches (Pullan *et al.*, 2001). Wherever possible the geophones were planted in the bottom of ditches in order to improve the high-frequency response resulting from coupling to water-saturated sediments. The source was an in-hole "Buffalo gun" (Pullan and MacAulay, 1987), which fires a 12-gauge blank charge into the ground from 1 m below surface in a narrow-diameter, drilled hole (tamped with water). The production phase of the seismic program involved the recording of continuous 12-fold common midpoint (CMP) profiles, such as those presented in this paper. In total, 5 line-km of 12-fold data were collected in the River Denys lowlands. All data have been processed by applying standard CMP sequences of processing steps, including trace editing, static corrections, bandpass filtering, gain scaling, velocity analysis, normal move-out corrections, and stacking of the corrected traces (e.g. Steeples and Miller, 1990).

Drilling Methods

Drilling methods were similar to those employed in the Musquodoboit Valley, which defined large areas of previously unknown silica sand and clay (Finck *et al.*, 1995; Gillis, 1998). For the first phase of drilling (March 2001) a large track-mounted drill

equipped with a wire line coring system was used (Feetham *et al.*, 2002). It was designed to give high recovery in unconsolidated sand and clay, and was extremely mobile. Materials could be quickly triconed if core was not desired. Drilling in the fall of 2001 was conducted using a smaller, more versatile, track-mounted rotary drill. This multi-purpose drill allowed for a variety of sampling techniques including augering, split spooning and coreing. Standard augers with a 4.5 inch diameter were used to quickly drill down through surface clay, sand and gravel. Grab samples were taken at 5 foot intervals from each auger. A 1.5 inch diameter, 2 foot long split spoon sample was obtained by driving a sampler ahead of the auger at the base of the hole. The drill was equipped with a 140 lb. hammer with a 30 inch drop. If ground conditions or materials became unfavourable for auguring or split spooning, the drill was converted to diamond-drilling. Drillholes were cased with 3.9 inch HW steel pipe to prevent hole cave-in. HQ core barrel and rods were used to obtain a 2.5 inch core sample. All holes were drilled vertically, and the casing was removed when the drillholes were completed.

Downhole Geophysics

Downhole geophysical logs provide a remote means of identifying stratigraphic units based on variations in their physical properties. These are especially useful in this study to cover gaps in the stratigraphic record from lack of core recovery in coarse sediment. The logs discussed in this paper include natural gamma, conductivity and magnetic susceptibility measurements acquired with a Geonics EM-39 portable logging system, and downhole seismic logs (Douma *et al.*, 1999).

Laboratory Methods

Clay samples from the area were tested to evaluate sedimentologic and ceramic properties. Utilization of clay as a resource material for ceramics and structural materials depends on a range of properties unique for each industry. For example, a brick manufacturer wants a large-volume source of moderately uniform clay that has a low shrinkage/swelling percentage, consistent firing colour, relatively low firing temperature, and good strength after firing. Testing was done to assess the suitability of the clay in southwest Cape Breton Island for both brick/tile and artware/pottery using laboratories at Hocking Technical College, Ohio, the Nova Scotia College of Art and Design (NASCAD), Halifax, and Mission Clay Products in Kansas. Testing procedures from Mission Clay laboratories are outlined in Appendix 1. Hocking College ceramic testing methods followed the standard methodology outlined in the manuals of the American Society for Testing and Materials (ASTM); ASTM C-20 for porosity, absorption, specific gravity and density, ASTM C-324 for moisture content, ASTM C-67 for modulus of rupture (MOR), and ASTM C-326 for dry and fired shrinkage (see www.astm.org for further information). NASCAD employed standard methods for the evaluation of pottery clay, as outlined in Rhodes (2000).

Samples were sent to the Dalhousie University Geotechnical Laboratory to establish basic hydrogeological and engineering characteristics including grain size, mositure content, liquid and plastic limit, and hydraulic conductivity. Tests were performed generally following standard methods from the American Society For Testing and Materials (ASTM D4959, D422, D1140, D4318, D5084).

A series of specific tests for aggregate quality was conducted on some of the sand deposits (Appendix 2), including grain size, the Los Angeles Abrasion Test (LAAT), soundness and petrographic analysis. These tests were conducted to determine the competence and durability of the aggregate compared with other sources, and are described in detail in Prime (1992). The LAAT is a measure of abrasion resistance made by rotating the materials in a drum and determining the weight loss. The soundness test is a measure of resistance to freeze/thaw and conducted by immersion in a sodium sulphate solution and drying. The chemical reactions induce expansion and contraction emulating freeze/thaw. Weight loss during the immersion cycles is compared to known standards. Finally, in the petrographic analysis rock types are grouped according to their hardness and acid reactivity and the percentages in each grouping are multiplied by a factor in each category (Excellent = 1, good = 3, fair = 6, poor = 10) to obtain a number between 100 and 1000. A petrographic number of

no greater than 135 is required for aggregate used in asphalt concrete in Nova Scotia.

Geology of the Clay and Sand Deposits

Up to 130 m of glacial sediment were deposited in the valleys and lowland basins of Inverness County. Almost all of this sediment was formed by glaciers, either directly as glacial till or indirectly by glacier meltwater (glaciofluvial and glaciolacustrine deposits). During the glacial periods glaciers advanced, eroding bedrock and existing glacial sediments and forming an unsorted mixture of clay, silt, sand and boulders known as glacial till[1] (Dreimanis, 1989). During glacial retreat glaciofluvial deposits were deposited under, on, or adjacent to the retreating glaciers (Goldthwait, 1989). Glaciofluvial deposits that formed near glacier ice are called ice contact stratified drift or more commonly kames and eskers (Fig. 2). These sediments often form irregular hills (kames) or sinuous ridges (eskers), reflecting the ice environments in which they were deposited (Fig. 2). Sediments deposited in front of the retreating glaciers, often in glacial lakes, are called outwash fans or valley train deposits. Outwash fans are gently sloping, fan-shaped plains consisting of coarse gravel at the head (closest to former ice sheet) and finer sand deposits at the outer edge. Valley trains are belts of outwash confined to valleys, locally pitted with kettle holes. It is sometimes difficult to distinguish between low relief, ice contact stratified drift and outwash. Outwash can be deposited at the margin of a calving glacier or into a body of water, either a lake or ocean (Fig. 2). Outwash that is deposited under water is called subaqueous outwash (Rust and Romanelli, 1975).

Fine-grained sediments deposited in glacial lakes are termed glaciolacustrine sediments (Fig. 2). In southwest Cape Breton Island these form a major part of the Quaternary basin fill of every lowland region and can exceed thicknesses of 50 m in some areas (Stea *et al.*, 2003; Fig. 1). Former glacial-lake bottom basins are characterized by flat to slightly rolling topography covered with sand, silt and clay. Shorelines of the former glacial lakes are marked by terraces and often glaciofluvial delta deposits. Linear meltwater channels, and sand and gravel deposits, mark meltwater spillways which fed into the former lakes. The clay deposits found in the Inverness County lowlands are unusually fine-grained and massive, lacking the graded beds with coarse silt and sand that often characterize glacial lake sediments (varves, cf. Ashley, 1995), and have a low percentage of dropstones (dropstones are larger rocks that have been carried into the lake by floating ice and later dropped by melting). The implication is that active glaciers were not directly calving into these water bodies, but had dammed the basin outlets in areas remote from the site of deposition. Glaciolacustrine deposits in Cape Breton Island can be divided into: (1) surface glaciolacustrine deposits (Moran-Hawthorne-Judique-River Denys basins), or (2) buried glaciolacustrine deposits (River Denys basin-River Inhabitants lowlands).

Surface glaciolacustrine deposits formed relatively recently, as the last ice sheets receded and glacial lakes filled the lowland basins dammed by glaciers and surrounding hills (Fig. 2). Buried deposits formed at various times in the Quaternary, but were later buried by tills formed by advancing glaciers, ice retreat sediments or later Holocene flood plain and colluvial sediments. What follows is a detailed description of the lowland basins where much of the sediment deposited by glaciers accumulated.

Surface Glaciolacustrine and Glaciofluvial Deposits

Moran-Hawthorne Basins

Clay deposits north of Judique infill wide topographic lows informally termed the Moran and Hawthorne basins (1 and 2; Fig. 1; Map 1). These fine-grained deposits are associated with sand and gravel, both vertically and laterally. The Moran basin was studied in the most detail, as high quality clay is found in association with a sand and gravel

[1]Till is a term referring to unsorted materials formed directly by glacier ice (Dreimanis, 1989). Diamicton is a corresponding term referring to unsorted sediment of uncertain genesis (Eyles *et al.*, 1983).

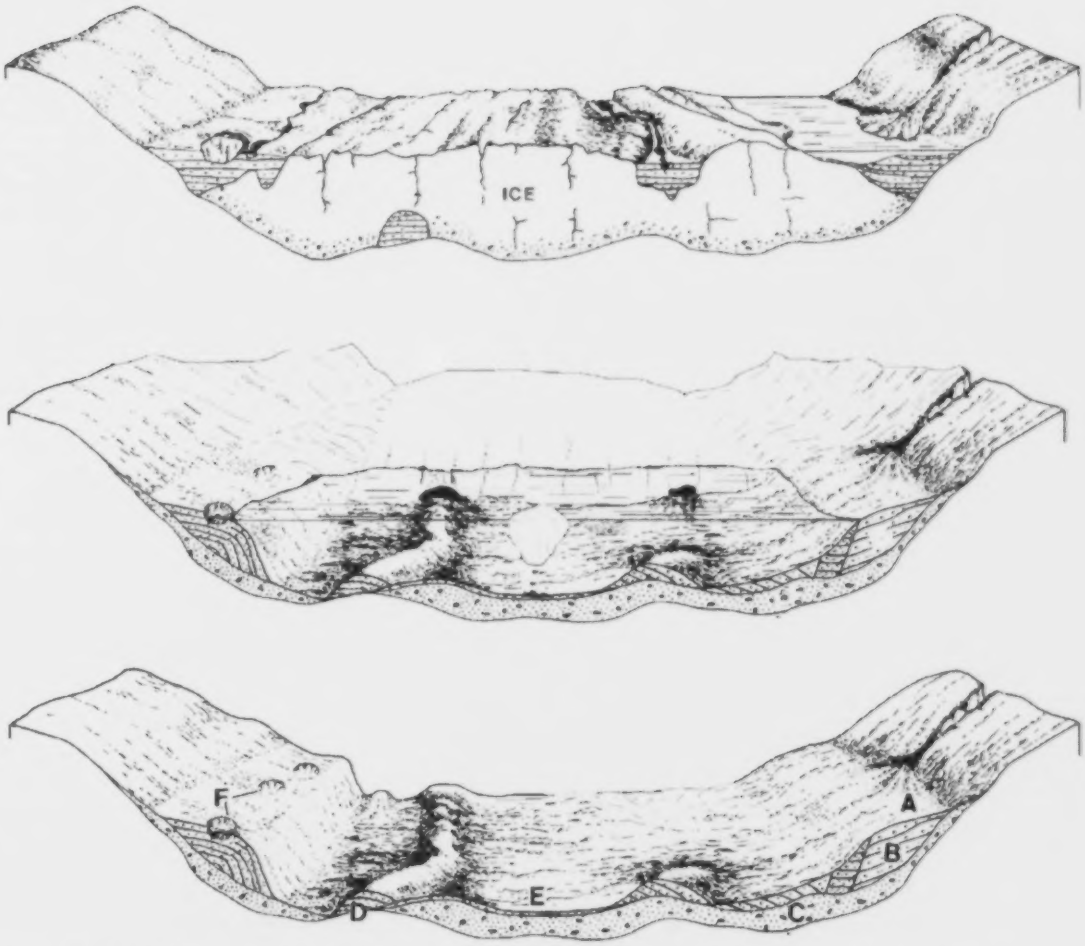

Figure 2. Schematic diagram showing the mode of formation of glaciofluvial and glaciolacustrine sediments in the lowlands of Cape Breton Island. **Top diagram**. An ice tongue is melting in the valley, and materials are deposited at the margins by glacial meltwater from the surrounding highlands, and at the base of the ice tongue as till or as glaciofluvial deposits in subglacial tunnels. **Middle diagram**. The ice tongue retreats up-valley and a proglacial lake is dammed in the valley between the ice and local highlands. Coarse material is deposited as subaqueous outwash at the glacier margin and clay and sand in the lake itself. **Bottom diagram**. Resulting deposits and landforms. A. ice contact delta, B. kame terrace, C. glacial till, D. esker, E. glaciolacustrine sediments, F. kettle holes.

deposit actively being mined, and the Moran basin is largely Crown land. The Hawthorne basin, by contrast, was sparsely sampled as it is being used as farmland and settlements.

Moran Basin Stratigraphy

Three drillholes (MB-01-1, 2, 3; Figs. 3, 4) were completed in the Moran basin to determine the stratigraphic relationships of the glacial sediments in the basin (Fig. 2). Six surficial stratigraphic units were delineated. Drillholes MB-01-1 and MB-01-2 bottomed in micritic limestone at 13 m and 30 m, respectively, and MB-01-03 did not reach bedrock. In drillhole MB-01-2 the limestone was underlain by grey-white gypsum. Resting on bedrock at both localities is a reddish-brown silty diamicton with local sandstone and limestone clasts interpreted as glacial till (Unit 1; see Fig. 4 for stratigraphy). Above the till is a cobbly-gravelly-sand unit with

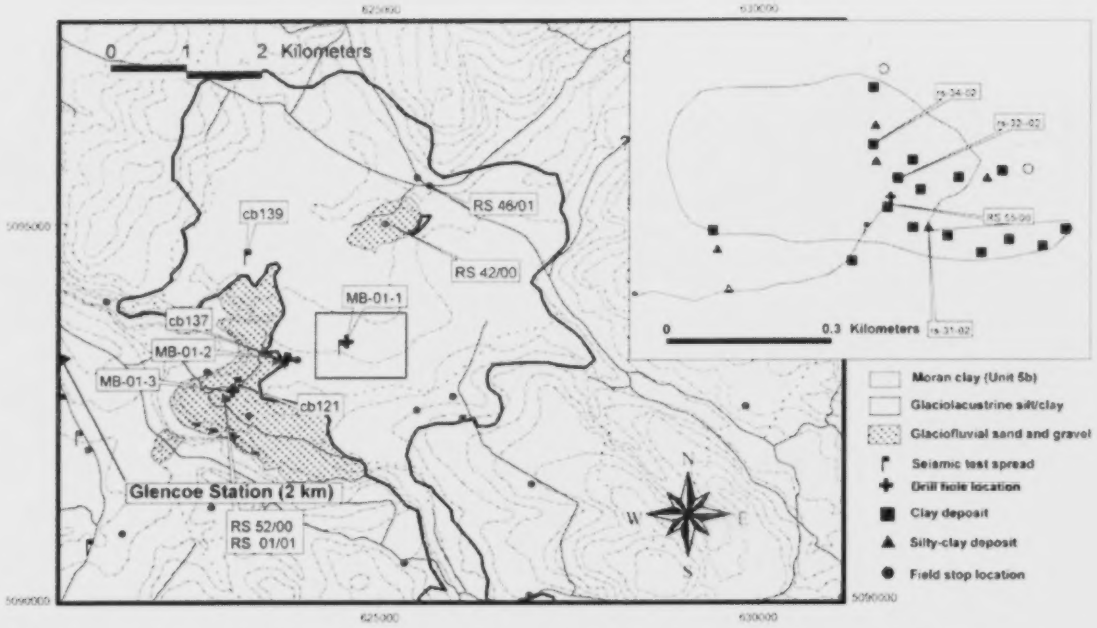

Figure 3. Detailed map of the Moran basin showing the location of seismic test spreads, drillholes, and field sites where samples were taken. Inset map depicts the approximate boundaries of the Moran clay unit (5b) within the Moran basin (area indicated by square in base map area).

abundant greyish-white tonalitic pebbles, the tonalite distinguished by epidote and altered mafic minerals (Unit 2a). Overlying this unit in the deeper part of the basin is a sequence of grey and reddish-brown laminated and massive silty clay (Units 3a, 3b). A thick coarse unit overlies Unit 3 in the middle of the Moran basin at depths >5 m below the surface, consisting of a bouldery gravel unit with granite components similar to Unit 2 (Unit 4b) grading into gravelly sand facies to the east (Unit 4a). The surface outcropping units consist of a laminated and massive reddish-brown silty clay and clay (Units 5a, 5b) found in the middle of the basin and an overlying gravelly sand (Unit 6a) at the edges. These units appear to be separated by sharp, erosional contacts. Unit 5b is the massive clay facies most desirable for exploitation as ceramic clay and was found to be 6 m thick at MB-01-3 and 2 m thick at MB-01-1. The continuity between drillholes was established by many hand augerings, which revealed clay (Unit 5b) at the surface over much of the Moran basin (Fig. 3). The sandy mud (Unit 5c) at the top of MB-01-2 also appears to be a lateral facies of Unit 5b, perhaps derived from reworking of nearby till highs.

At site 55/00 (Fig. 3) the detailed stratigraphy of the Moran clay deposit (Unit 5b) was revealed by several backhoe excavations (Fig. 5). The soil profile (D; Fig. 5) is approximately 30-40 cm thick and overlies about 1.5 m of blocky clay (C) with numerous fractures lined with organic material, probably roots. Below this lie 1.5 m of massive clay (B = Unit 5b; Fig. 4) which overlie a silty clay unit at a depth of 3.3 m below surface. This silty clay unit features interbeds of brown silt and fine sand 1-3 cm thick, which become thicker and coarser down section (A = Units 5a, 5c; Fig. 4).

Test seismic spreads completed in the Moran basin (Pullan *et al.*, 2001) provide an idea of the depth and continuity of the glaciolacustrine facies. Site cb121 (Fig. 6), in the vicinity of drillhole MB-01-03 (Fig. 3), shows reflection energy at the top of the section interpreted to result from a silt/sand layer within Unit 5b (9-13 m depth), underlain by a transparent facies to ~40 m depth. The reflection package at ~40 m depth is interpreted as the bedrock surface. The thick transparent seismic facies suggests that the clay facies (Unit 5b) and underlying fine-grained deposits extend to considerable depths (~40 m) at this site. Site cb136

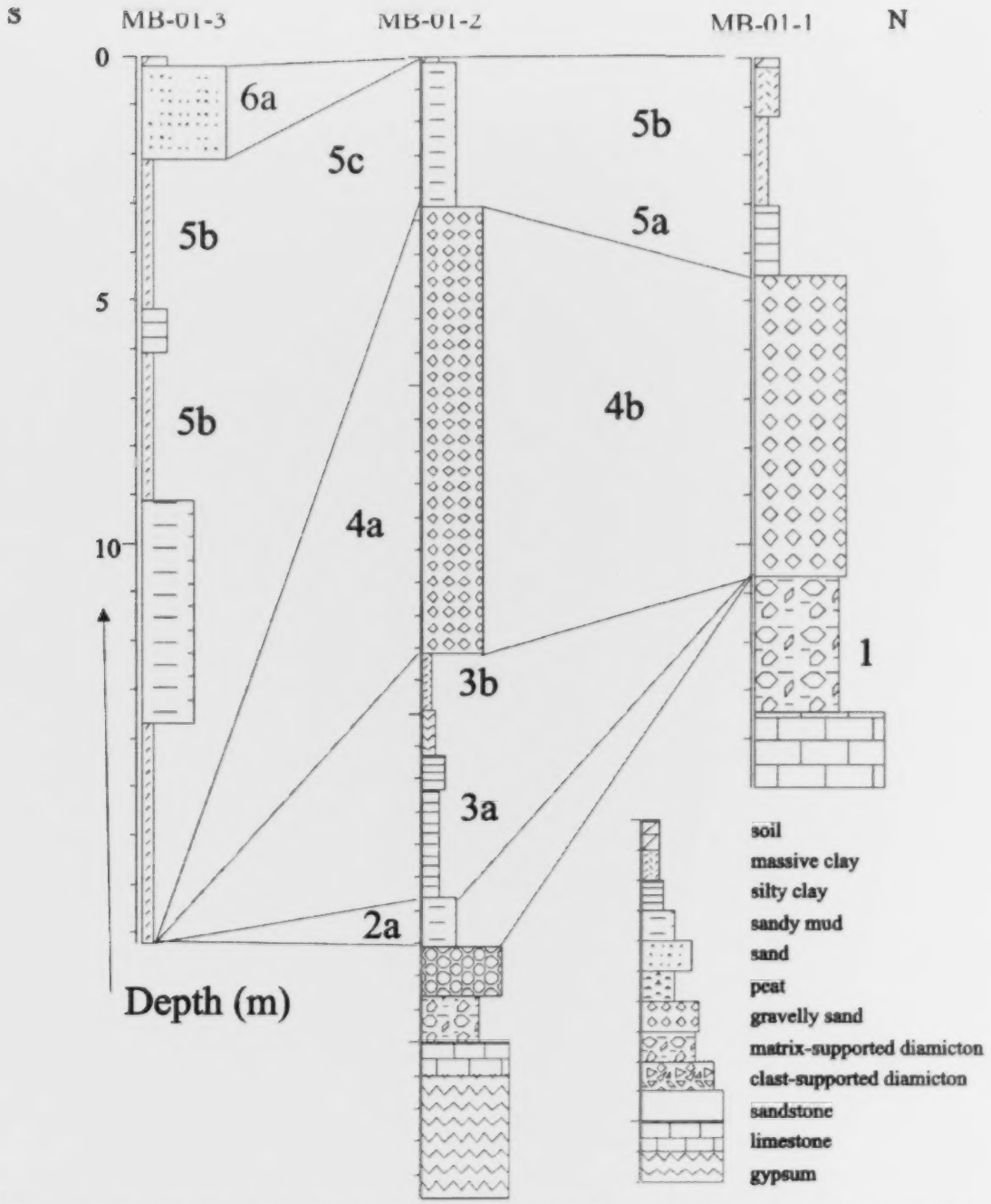

Figure 4. Stratigraphic logs of three drillholes in the Moran basin (see Fig. 3 for locations). Log widths are proportional to the mean grain size of sediments with thin logs representing fine-grained sediments and thicker logs representing coarser sediments. The maximum log thickness corresponds to indurated bedrock.

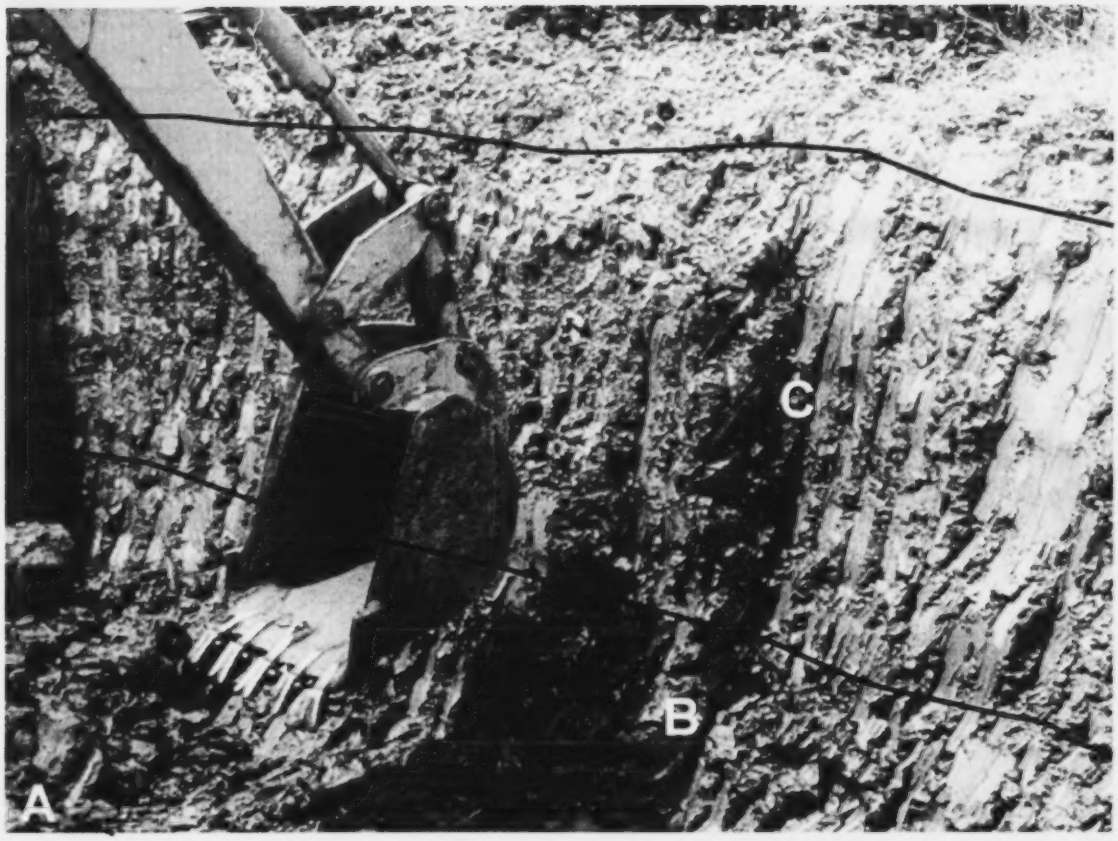

Figure 5. Backhoe excavation of a clay deposit at site 55/00 in the Moran basin (Fig. 3). A: Units 5a, 5c; clay with silt and sand beds, B: Unit 5b; massive silty clay, C: blocky silty clay with rootlets, D: soil horizon.

(Fig. 6) shows good data quality with a prominent refraction breakover, indicating shallow, high-velocity bedrock (4830 m/sec) at ~12-15 m verified by the drillhole record (MB-01-1) At this site the overlying stratigraphy is too shallow to be imaged by seismic reflection techniques. Unit 5b at this site is represented by sediment with velocities of 1530 m/sec. Site cb137 in the vicinity of drillhole MB-01-2 (Fig. 3) yielded poor quality data (low frequency) that are interpreted to indicate a thin high-velocity surface layer overlying dry sediments. A hint of reflection at ~30 m water depth corresponds to the bedrock surface observed in the drillhole. Sites cb136, cb137 and cb121 show that the clay deposit (Unit 5b) of economic interest increases in thickness from ~2 m in the east to ~15 m under the glaciofluvial gravel deposits nearest the Mabou River (Fig. 2). Seismic data acquired at site cb139 (Fig. 6) in the northern part of the Moran basin (Fig. 3) are more difficult to interpret stratigraphically (Stea *et al.*, 2002). At this site, seismic velocity increases gradually with depth and a layered refraction interpretation is likely a poor representation of the subsurface structure. Bedrock is estimated to be at ~15 m depth, based on the velocities determined there, but no high-velocity breakover is observed. It is suspected that the surface clay at this site (1630 m/sec) may be underlain by coarser deposits (~2500 m/sec; including perhaps sand, gravel and/or till), with little velocity contrast between these sediments and bedrock. The seismic section also implies that the bedrock in this area is not the high-velocity limestone observed at site cb136.

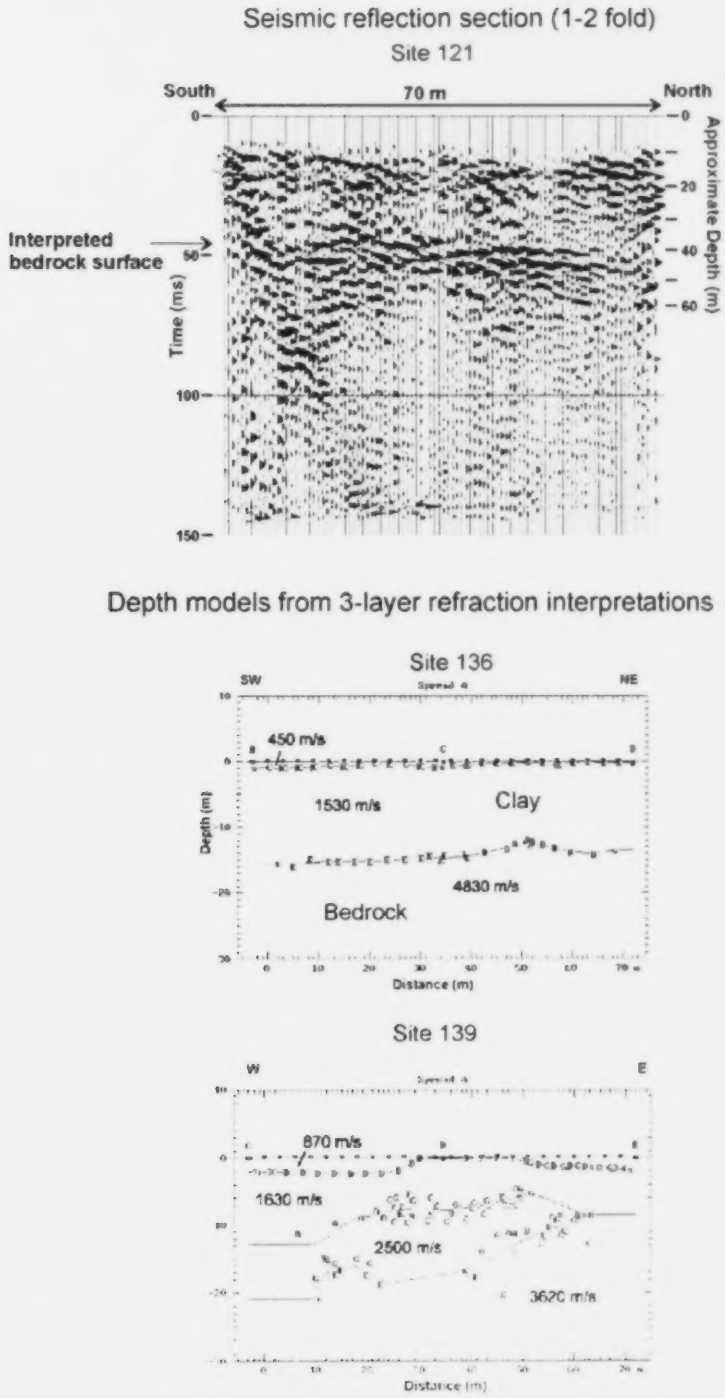

Figure 6. Seismic reflection profile at seismic test site 121. Refraction depth models at seismic test site 136 and 139.

Glaciofluvial Deposits

Glaciofluvial sand and gravel deposits are thickest and coarsest in the south side of the Moran basin. At site 52/00 (Fig. 3) in the Moran pit a massive, bouldery, gravelly sand constitutes the bulk of the deposit, incised with channels of openwork cobbles. Gravel lithologies include grey and red conglomerate and massive siltstone (50%), tonalitic granite (40%), and diabase/gabbro(<10%). Just east of site 52/00 the deposit grades into a coarse to medium, cross-bedded sand with little gravel. The cross-beds dip toward the northeast. There is an isolated deposit of pebbly sand at site 42/00 (Fig. 3). The deposits become finer-grained to the north and northeast, but do not appear to be facies equivalent with the fine-grained surface clay deposits in the basin (Unit 5b). The seismic sections and drillholes suggest that the southern gravel deposits are equivalent to Unit 6 and overlie clay deposits.

Judique Coastal Plain

Judique Coastal Plain Stratigraphy

Near Judique, glaciolacustrine deposits are found along the coastal plain between the Creignish Hills and the Gulf of St. Lawrence (Fig. 1; Map 1). Sea-cliff exposures reveal four main facies: stony clay (diamicton), massive clay, laminated silty-clay/sand, and laminated sand. In the northern Hawthorne and Moran basins (Fig. 1), massive clay and stony clay appear to be the predominant facies, whereas the Judique coastal plain features extensive sand deposits that interfinger with fine-grained deposits, both laterally and vertically.

Coastal exposures near Judique reveal a continuous surface unit of sand and clay (Unit 4), which can be traced laterally for 5 km, draped over older glacial deposits and topography. At site RS28/01 (Centennial Road section; Fig. 7) a continuous peat and clay layer (Unit 3) separates till, sand and clay facies (Units 1-2) from the upper draped silt, sand and clay unit (Unit 4; Figs. 7, 8, 9). The upper draped unit sand has two facies: a parallel-laminated sand with thin beds consisting of normally graded coarse to fine sand (Unit 4a) overlain by massive, red-brown, blocky silty-clay (Unit 4b).

Farther north along the coast from section RS 28/01 the sandy facies of Unit 4 pinches out over silty/clay rhythmites and bouldery-gravelly-sand (Units 2a, b; Fig. 8). The Campbell site (RS 38/01; Fig. 7), discovered by D. R. Grant in 1970, reveals an organic zone, overlain by a massive sand unit, and underlain by sand and till (Grant, 1994). The sand unit was originally interpreted as glaciofluvial, but the lateral and vertical interfingering relationships with clay units and normally graded sand beds suggest a distal, subaqueous outwash origin (Ashley, 1995).

Glaciolacustrine sediments overlying the peat paleosol marker horizon can be traced inland near Judique South to elevations of between 60 and 70 m (Map 1; Fig. 7). At site RS117/01 (Fig. 7, 8), 1 m of brown, massive and laminated silty-clay (Unit 4b) overlies peat (Unit 3a). A sandy clay unit (Unit 2b) underlies the peat/organic marker, resulting from earlier glacial lake deposition. This section is nearly identical to one described in the town of Judique (RS184/01; Stea and Mott, 1998), where as much as 3.4 m of massive clay (Unit 4b) was found overlying a thin peat layer, below which there is another massive, glaciolacustrine clay (Unit 2b). This clay unit (4b) outcropping in the town of Judique (Fig. 11) is texturally similar to the surface clay unit of the Moran basin (5b).

Farther south at Long Point is a deposit described as ice contact stratified drift by Grant (1994). Coastal exposures reveal mostly waterlain sediments, dominated by a sand unit characterized by graded beds (coarse to fine sand), with silty/clay seams, thin beds of coaly material, and cross-bedded sand. Faults cut through the sand unit. The graded sand beds are overlain on the north side of the Long Point exposure by a channelized, pebbly gravel and sand unit (Fig. 10). The lower graded unit and associated fines suggest a subaqueous origin, perhaps proximal subaqueous outwash from a retreating ice mass to the southeast that was debouching sediment in a glacial lake dammed between it and a Gulf of St. Lawrence ice mass. The coaly material in the graded sand unit is perhaps derived from coal-bearing strata in the Gulf of St. Lawrence or to the southeast along Inhabitants Bay (Stea *et al.*, 2003). The coarse gravelly channels are subareal in origin, and likely

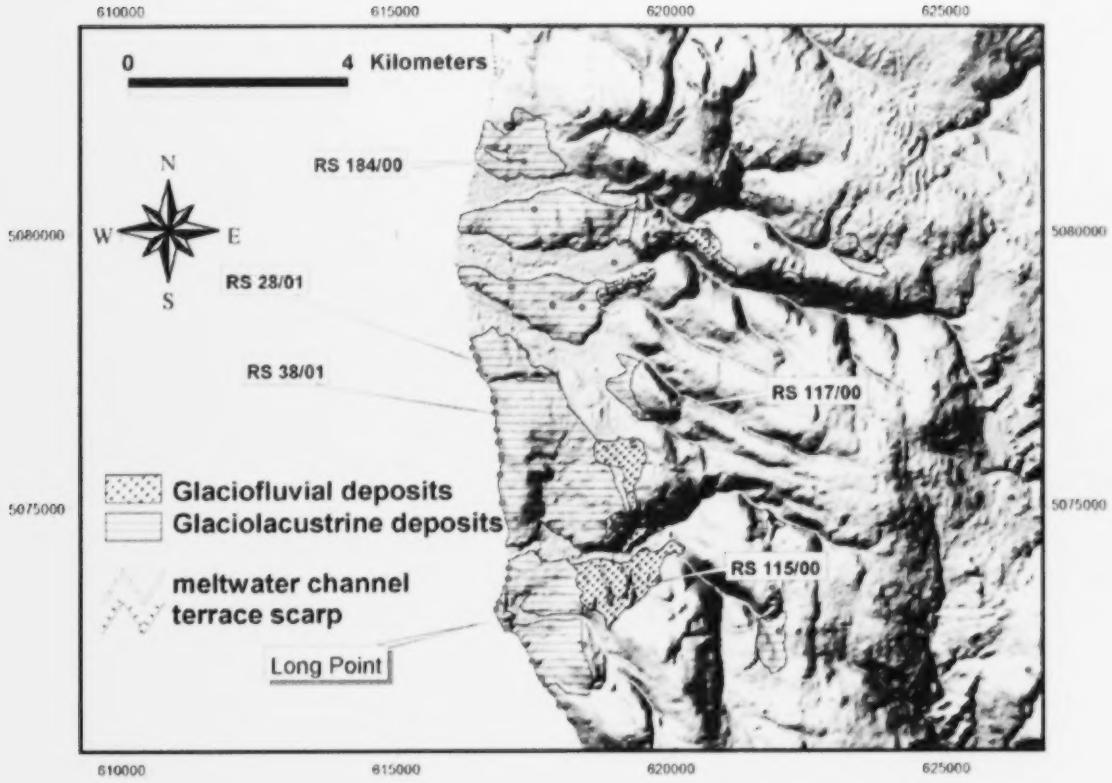

Figure 7. Surficial geology of the Judique coastal plain and location of stratigraphic sections.

relate to a period of early Holocene fluvial activity (Grant, 1994).

Glaciofluvial Deposits

There are a number of small sand and gravel deposits of glaciofluvial origin that are found along the terraced shorelines of the Judique glacial lake basin and probably represent outwash delta deposits (Stea *et al.*, 2003). Several flat-topped exposures reveal gravelly sand and sand deposits, with thicknesses up to 20 m, but lack any freshly cut exposures. One section (115/00; Fig. 7) revealed a faulted medium to coarse sand overlain by channelized gravelly sand indicating a westward meltwater flow.

Farther south near Craigmore, there are isolated knob-shaped deposits of sand and gravel at higher elevations along the flanks of the Creignish Hills (Fig. 1; Map 1). One deposit, presently being mined, is composed of bouldery gravelly sand and cross-bedded coarse to fine sand, cut by faults. These deposits are classified as ice contact stratified drift.

River Inhabitants Lowlands and Queensville Area

Sand and gravel deposits are found on the southern end of the River Inhabitants lowlands associated with knob and kettle topography along a broad terrace on the east side of the River Inhabitants (Fig. 1; Map 1). The deposits consist of channelized, gravelly sand units on the surface, overlying parallel-bedded, graded, fine to medium sand and coarse sand to granules. Deposits are 3-5 m thick in pit exposures. Faults displace some of the sand beds (Fig. 11). The origin of these deposits

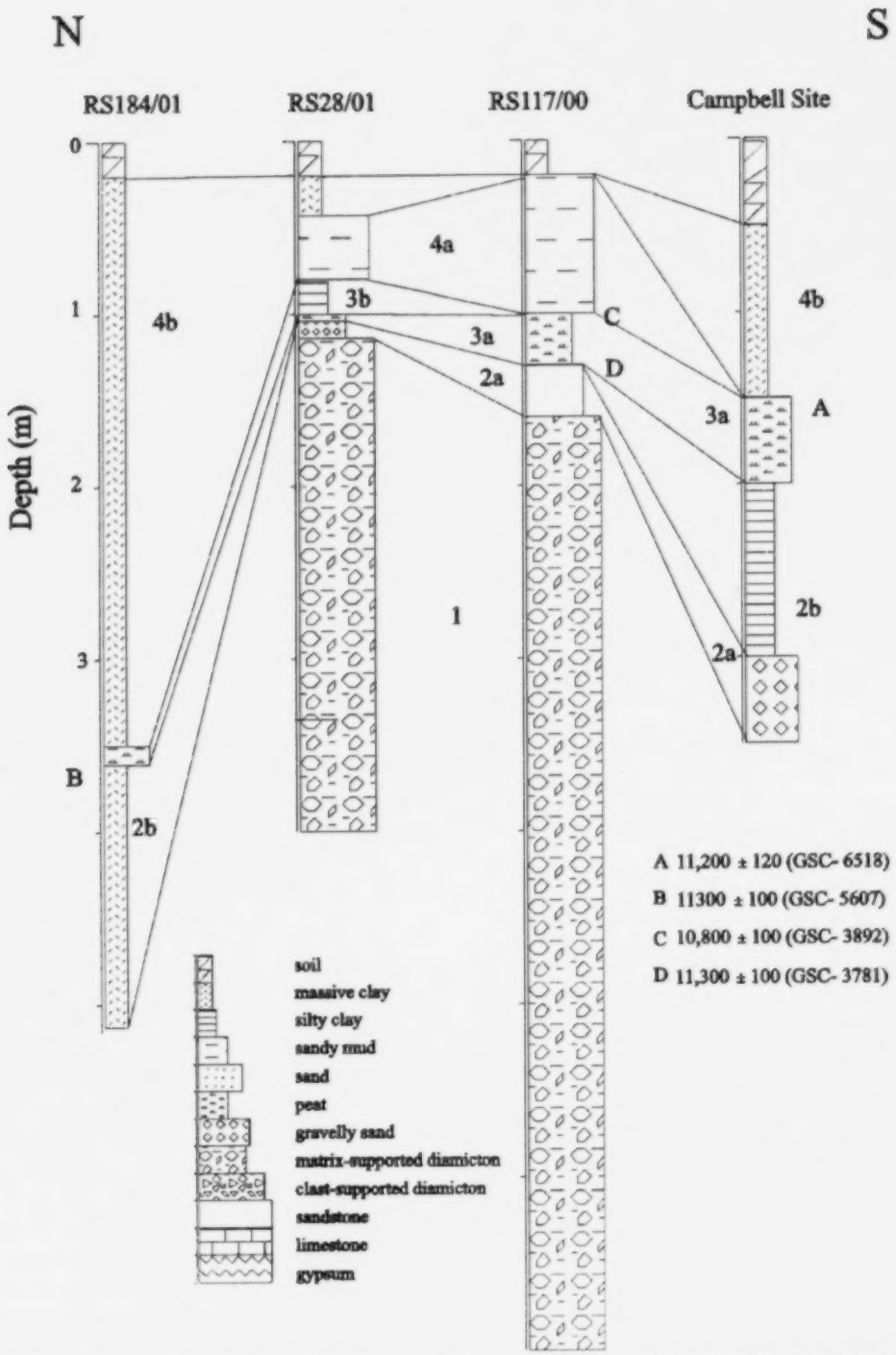

Figure 8. Stratigraphic sections in the Judique coastal plain area showing the stratigraphic units and proposed cross-basin correlations. Unit descriptions are found in the text. Radiocarbon dates from the peat/organic marker horizon are shown.

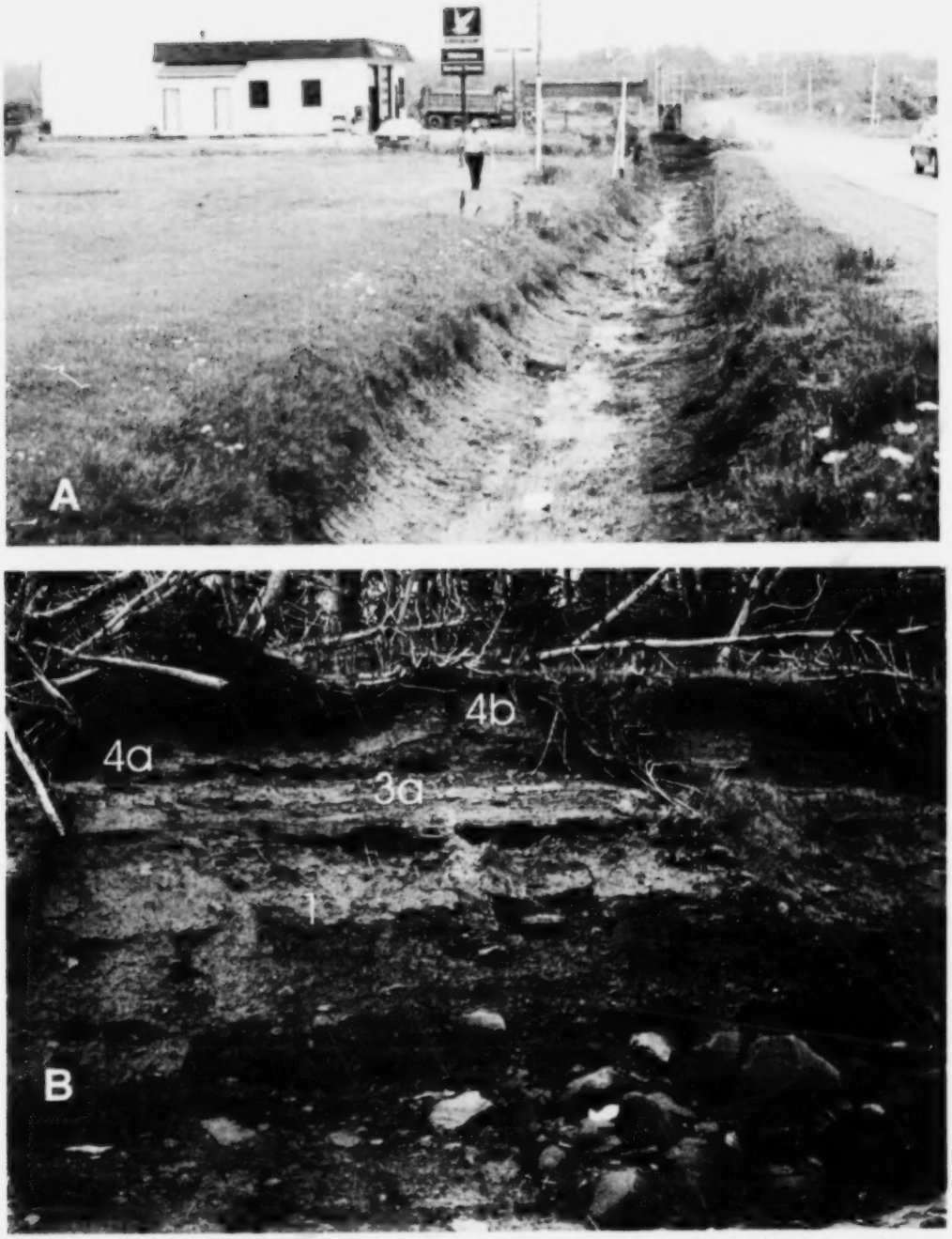

Figure 9. (A) Clay plain in the village of Judique. Massive silty clay (Unit 4b) outcrops in the road cut. (B) Photo of Site 28/01 showing the glacial and interglacial units depicted in Figure 10. Unit 3a is the peat layer that was radiocarbon dated.

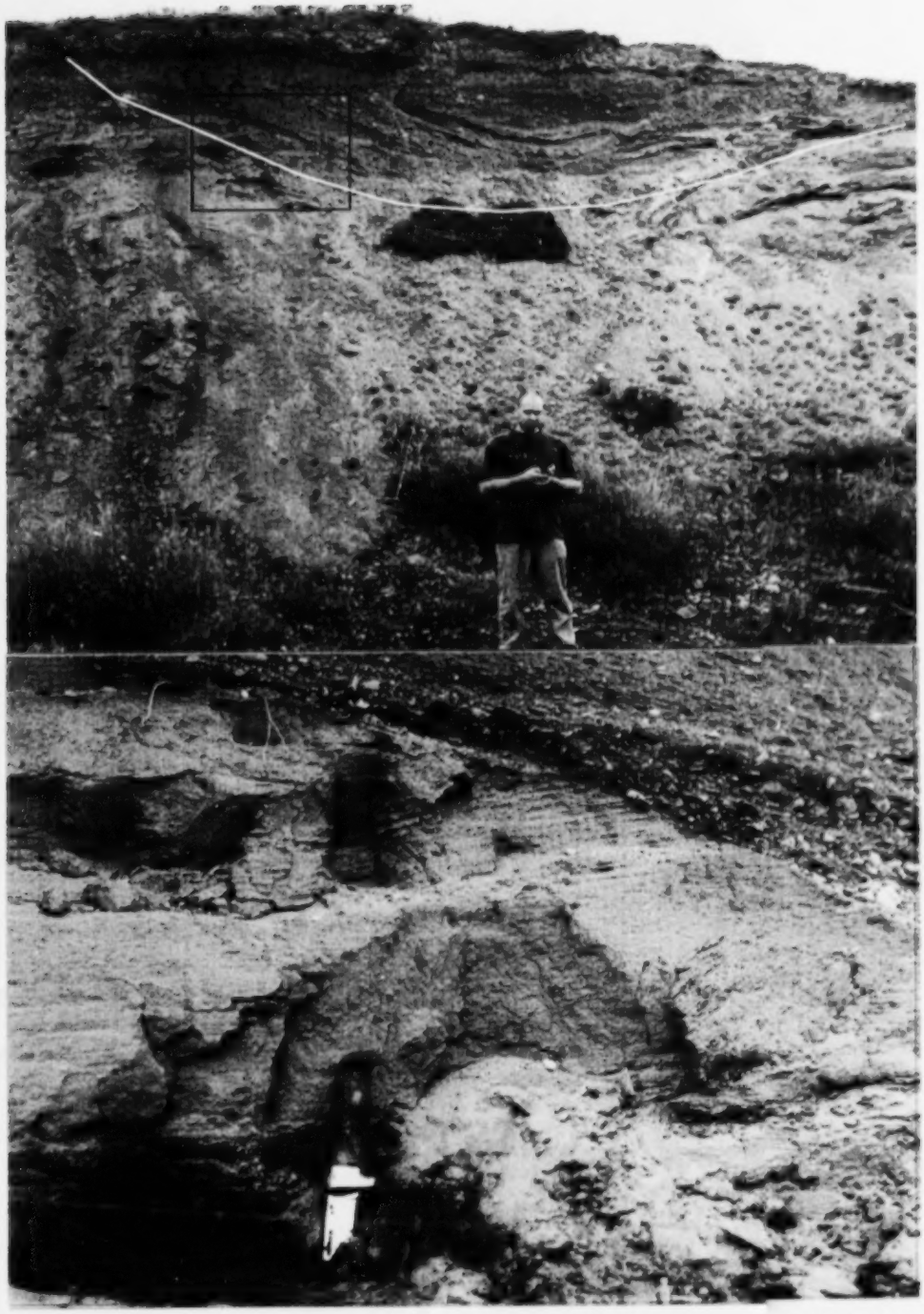

Figure 10. (Top) Subaqueous outwash (lower unit) consisting of coaly sand and fine sediments overlain by Holocene(?) alluvial gravelly sand in the form of a channel. (Bottom) Close-up of contact. Coaly layer occurs at knife.

Figure 11. Hummocky kame deposits of coarse to fine sand along the River Inhabitants. A fault is marked with the line.

is uncertain but likely to be ice contact stratified drift based on the hummocky surface topography and pervasive post-depositional faulting at the sections. The extent and nature of surface glaciolacustrine sediments in the River Inhabitants lowlands is poorly understood (Fig. 1; Map 1). Road exposures reveal a variety of sediment types, from gravelly sand to a loose silty diamicton, (possibly till "windows" in the lake plain) or a stony lake clay deposit. Glaciofluvial sand deposits adjacent to the basin in the Queensville area (Map 2) interfinger with clay deposits (Shea and Wallace, 1962, p. 70) and are interpreted as deltaic (Grant, 1994).

Large areas of the River Inhabitants lowlands are covered by deposits formed during flood stages of the River Inhabitants (Map 2). These deposits vary in thickness from 1 to ~6 m and consist of grey organic clay and peat overlying fine sand and, locally, gravelly sand deposits.

River Denys Basin

Extensive surface clay deposits are found near the mouth of River Denys in the vicinity of Eden and Valley Mills (Fig. 1; Map 1). These deposits consist of massive silty clay, fine sand and minor gravel. As stated earlier, at the turn of the Twentieth Century some of the clay deposits near the CNR railway line were utilized for brick manufacture. The thickness, extent and stratigraphy of these deposits, however, are not well understood. Glaciofluvial deposits of the ice contact type are presently being mined for sand and gravel and are closely associated with these fine-grained, glacial lake sediments.

A section at the main gravel pit near Valley Mills (I-75; Appendix 2) shows three major units (Fig. 12).

1. A coarse, gravelly sand and sand package forming the core of a linear ridge (Unit 1).

Figure 12. Photo of a glaciofluvial deposit presently being mined for aggregate near Valley Mills. The deposits consists of an older ice contact deposit (esker), Unit 1, which is overlain by subaqueous outwash deposits (Units 2 and 3).

2. Parallel-bedded, medium to fine ripple-laminated sand, generally becoming finer grained upsection (Unit 2).
3. Ripple-laminated fine sand changing upsection to sand and silty/clay rhythmites. Faulting of beds is common (Unit 3).

The coarser gravel and sand unit (Unit 1) in the core of the ridge is overlain by finer-grained sediments (Units 2 and 3) with an onlap relationship. It is not clear whether Units 2 and 3 are coeval with the glaciolacustrine massive silty clay surrounding the landform, or ice contact facies deposited earlier in an ice crevasse or as subaqueous outwash from a retreating, tidewater ice margin.

Buried Glaciolacustrine Basins: River Inhabitants Lowlands

The lowland regions of southwest Cape Breton Island host extensive deposits of glaciolacustrine clay and sand. In the River Denys lowlands, for example, buried clay deposits attain a maximum thickness of 60 m. These clay deposits are buried under surface glacial and river deposits and interbedded with glacial till deposits. Economic exploitation of these deposits may be unwarranted. in some areas, due to the prohibitive depth of the deposits and the relationship to the regional water table. Assembling the stratigraphic architecture of these basins, however, is an essential guide to the use of water resources, engineering aspects of construction design and environmental planning, and mineral exploration.

River Inhabitants Lowlands Stratigraphy

Based on seismic reflection testing (Pullan *et al.*, 2001) and previous indications of deep surficial cover, six drillholes were completed throughout the River Inhabitants lowlands (Figs. 13, 14). A stratigraphic profile from north to south across the lowlands was constructed using drillholes KV-01-2, KV-01-1, DR-01-1, BR-01-1 and ML-01-1 (Fig. 14). Within the lowland region is a previously described natural exposure of Quaternary sediments at River Inhabitants (Grant, 1994) and a new exposure at the Sugar Camp gypsum quarry (Stea *et al.*, 2003). The Sugar Camp gypsum quarry (Fig. 15) is designated in this study as the type section for the Quaternary stratigraphic units of the lowland regions of southwest Cape Breton Island. The East Milford Quarry section (Mott and Grant, 1985; Stea *et al.*, 1992) is an equivalent

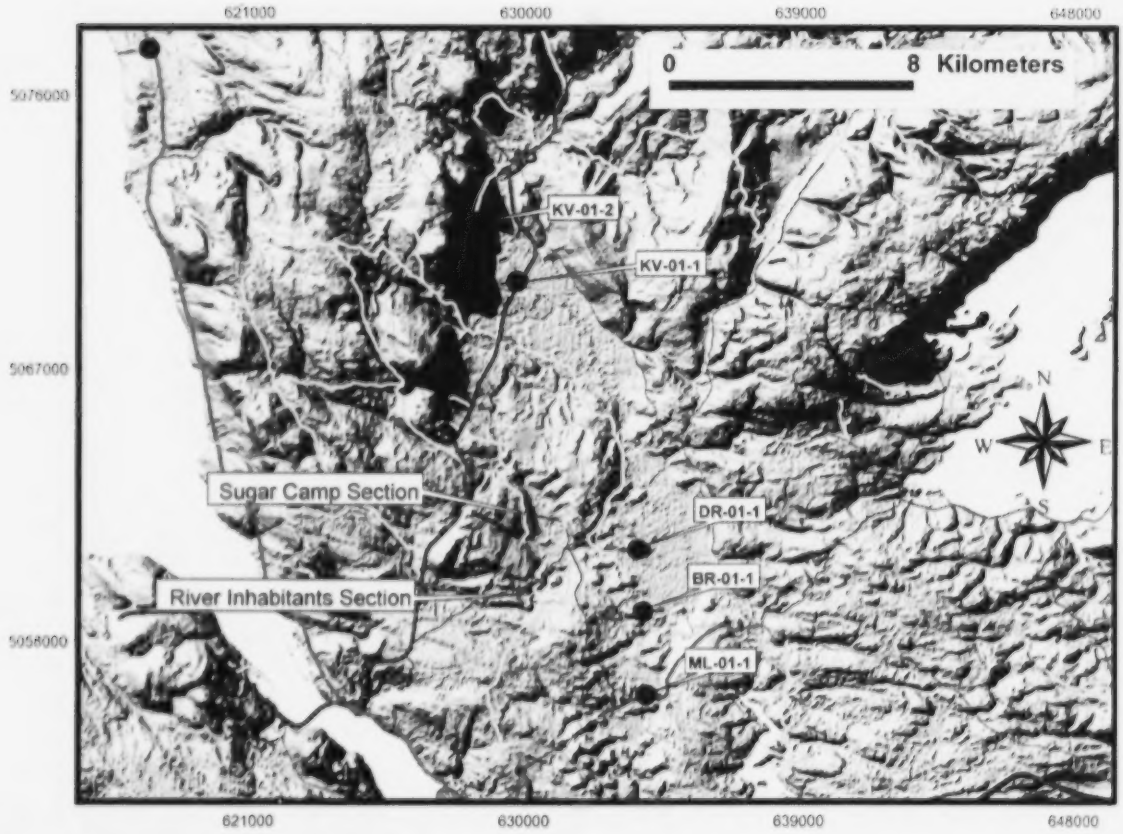

Figure 13. Location of reference sections and TGI diamond-drill holes in the River Inhabitants lowlands.

stratigraphic section on mainland Nova Scotia. The stratigraphic units within the lowland basins will be described from the oldest (bedrock) to the youngest (river alluvium).

Bedrock

Windsor Group evaporites, biogenic and clastic rocks underlie most of the River Inhabitants lowlands and are overlain by thick Quaternary sediments. In the southern part of the lowlands near Sugar Camp, grey-white carbonate-rich gypsum with nearly horizontal bedding was intersected at a depth of 14.2 m (DR-01-1) and 51.5 m (BR-01-1; Fig. 14). At ML-01-1 near MacIntyre Lake, bedrock is an alternating green and maroon laminated mudstone with some mottling, characteristic of the Mabou Group (R. Boehner, personal communication, 2002).

In the northern part of the River Inhabitants lowlands, none of the drillholes intersected bedrock (KV-01-1, 2; Fig. 14). The lowermost unit encountered in drillhole KV-01-1 was a light blue-grey, silty clay and breccia containing pebbles of pink gypsum and satin spar veins near the base. This unit featured dark grey to black silty clay, with abundant carbonate boulders, that was barren of palynomorphs (R. Fensome, personal communication, 2002).

Lower Till

The oldest Quaternary glacial deposits in the River Inhabitants lowlands are gravelly deposits overlain by a grey-brown to dark grey, matrix-supported silty diamicton (till) with gypsum and limestone

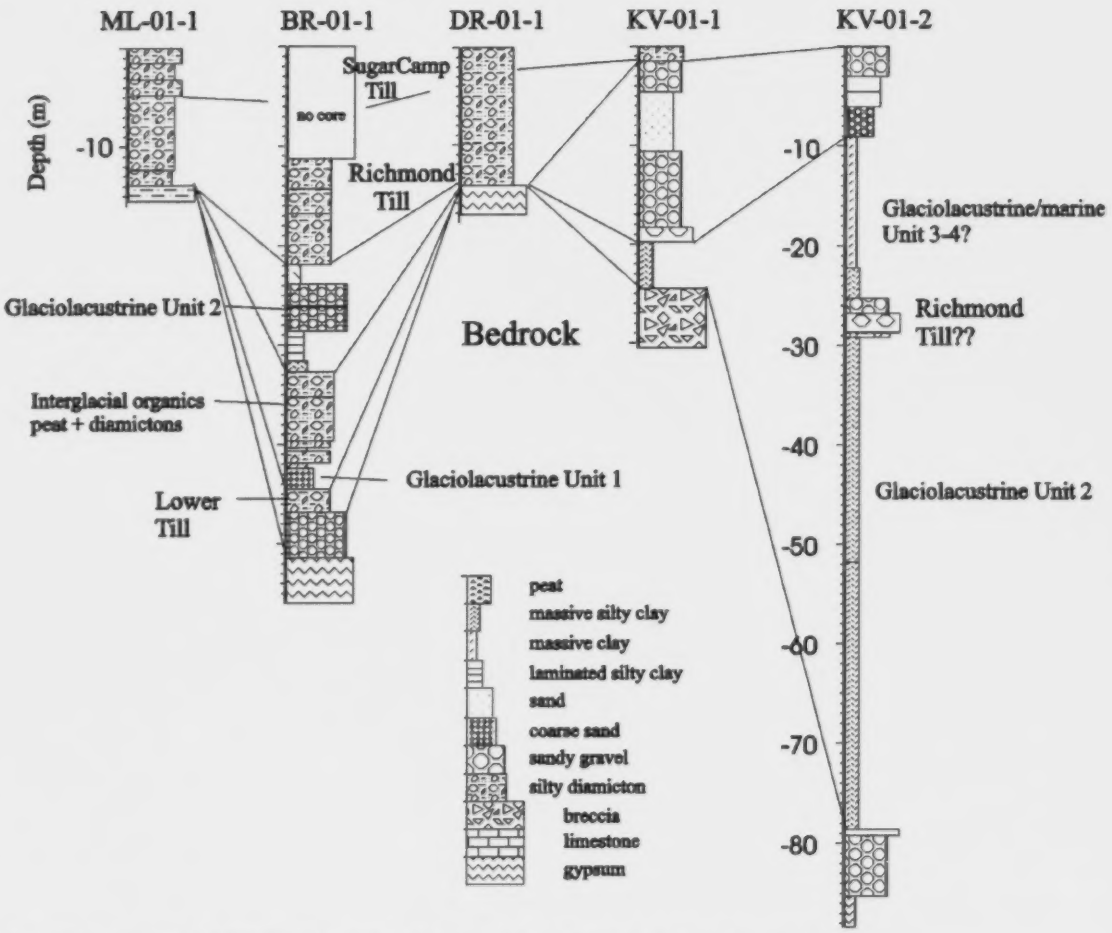

Figure 14. Stratigraphy and correlation of TGI drillholes in the River Inhabitants lowlands.

clasts. These units were observed in the Sugar Camp Quarry sections (Fig. 15) and at the Barbarton Road drillhole (BR-01-1; Fig. 14). Locally, layers of woody debris, including large pieces of wood, are found within the till unit, as are boulder layers.

River Inhabitants Glaciolacustrine Unit 1 (RI-GL1)

Overlying gypsum bedrock at the Sugar Camp Quarry is a brownish, silty clay diamicton (Lower Till?) with few clasts, which changes upsection into a rhythmically laminated silty clay and sand with calcareous concretions (RI-GL1; Fig. 15). These varved sediments are interpreted as glaciolacustrine.

Interglacial Peat-Paleosol

When the glaciers first retreated during the last interglacial (warm period) in Cape Breton Island the first glacial lake unit (RI-GL1) formed after drained forests were established on the newly exposed landscape. At the Sugar Camp Quarry (Fig. 15) unit RI-GL1 is overlain by ~3 m of organic silty clay with layers of peat and woody debris. This interglacial organic layer with wood fragments represents a marker horizon that can be used to stratigraphically separate similar glaciolacustrine facies of differing ages. A reference section of interglacial organics for the region is the River Inhabitants section described by Mott and Grant (1985), Grant (1994) and Stea *et al* (2003). The section features a thick interglacial

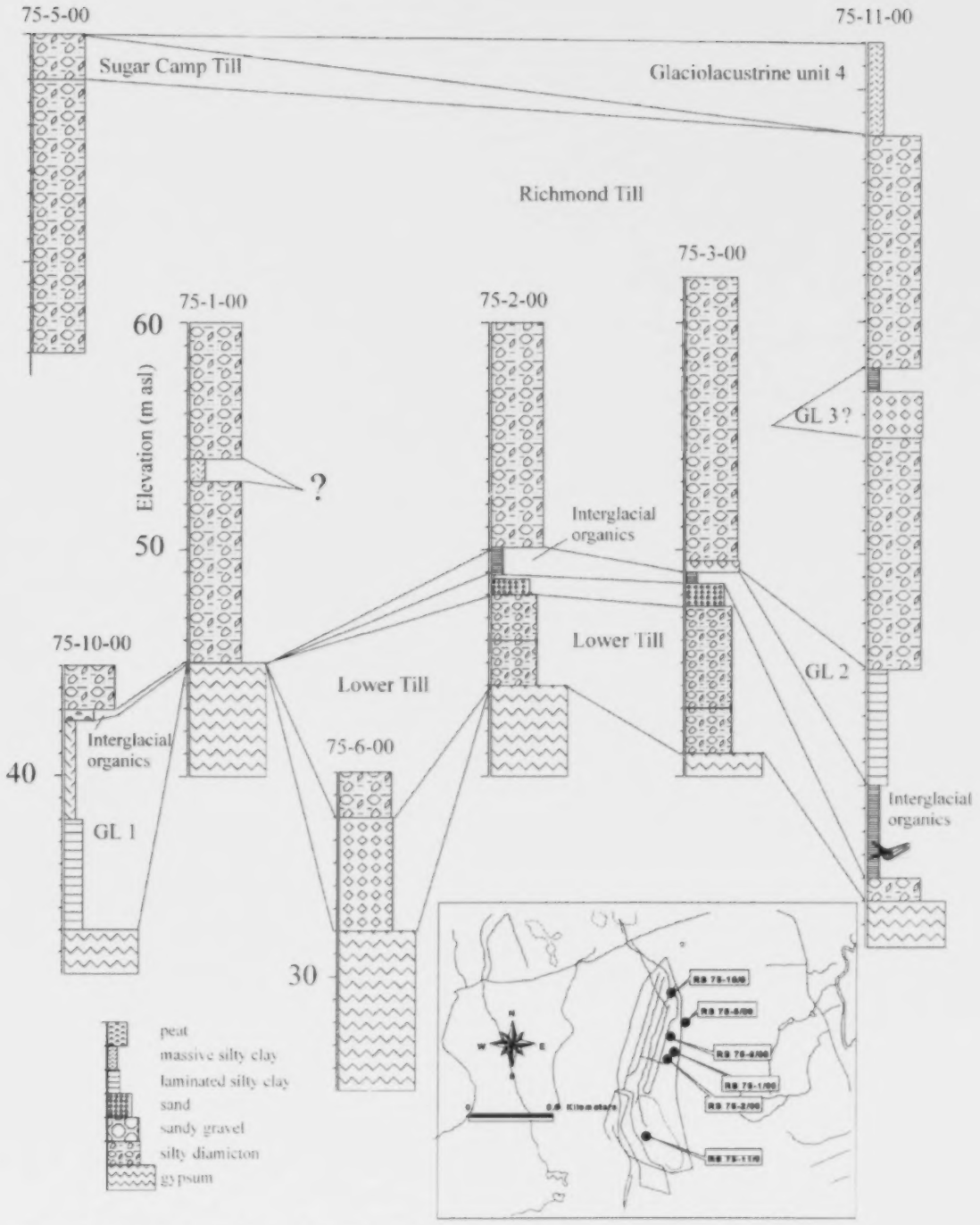

Figure 15. Stratigraphic sections, pit locations and correlation of units from the Sugar Camp Quarry.

peat zone, overlain by colluvium and then two till sheets. At Sugar Camp Quarry an organic silty clay of variable thickness, with peat and wood, is found near the base of the quarry section (e.g. 75-11-00; Fig. 15) both underlain and overlain by inorganic glaciolacustrine sediments (RI-GL1 and 2). Large pieces of wood at the base of RI-GL2 were recovered at several sites and identified as spruce (Picea) and fir (Abies) (R. J. Mott, personal communication, 2001). An accelerator mass spectrometry (AMS) radiocarbon date on one piece of wood produced a finite age of 42,600±1900 yr. B.P. (R. J. Mott, personal communication, 2001).

At the Barbarton Road drillhole section (BR-01-1; Figs. 13, 14) the lower till unit is overlain by ~5 m or organic diamicton and silty clay, and a thin layer of peat and wood representing a non-glacial interval of unknown duration and paleoclimate. The similarity in stratigraphic sequences strongly suggests that the nonglacial units in the Barbarton Road drillhole and in the Sugar Camp and River Inhabitants sections are correlative.

River Inhabitants Glaciolacustrine Unit 2

At Sugar Camp Quarry ~4-6 m of rhythmically bedded silty clay and sand overlie interglacial grey organic clay (gyttja?) with wood fragments (75-11-00; Fig. 15). The contact is gradational and conformable with organic grey clay featuring rhythmically bedded couplets of coarse and fine sediment, gradually replaced upsection by inorganic reddish-brown silty clay and sand beds.

Lying above the organic diamicton facies in drillhole BR-01-1 is a ~10 m thick package of waterlain sediments beginning with red-brown, highly deformed clayey silt, which becomes finely laminated (varved) upsection (BR-01-1; 31.6 m-28.6 m; Fig. 14). The waterlain sediments are interrupted by a thick sequence of coarse, gravelly ice-proximal sediments.

Richmond Till

At the Sugar Camp quarry sections a thick, massive grey-red, silty diamicton (till) overlies the organic clay and glaciolacustrine rhythmites (GL-2) with an erosional contact (Fig. 15). This massive, silty till has been called Richmond Till by Grant and King (1984), as it forms the core of many large drumlins in Richmond County. In the Barbarton Road drillhole nearly 10 m of grey-red, polymictic, matrix-supported diamicton (till) overlies interglacial organic layers (Fig. 14) and is interpreted as Richmond Till, the first regionally correlative till unit deposited after the last interglacial.

River Inhabitants - Glaciolacustrine Units 3 and 4 (?)

The Kingsville drillhole (KV-01-2) is situated on the River Inhabitants floodplain, which is blanketed by ~6 m of Holocene alluvial sand. Under the sand lie nearly 15 m of reddish-brown, massive silty clay (KV-01-2; Fig. 14) which rests on a reddish silty till correlative with the Richmond Till. The stratigraphic position of this unit is unclear, but it is not apparently overlain by glacial advance deposits. Stream erosion may have removed till from the upper part of the section, but it is likely that the unit postdates the last glacial retreat from the area. The conductivity log of KV-01-2 (Fig. 16) shows a peak in the unit greater than 300 mS/m, suggesting brackish formational water in the unit (Douma and Nixon, 1993; Hyde and Hunter, 1998). This peak may indicate a marine influence, but the presence of salt and gypsum bedrock in the basin (Boehner, 1986) may also explain the high pore water conductivity (see also Groundwater section).

Sugar Camp Till

At Sugar Camp Quarry the youngest till unit (Fig. 15) recognized in the study area is a reddish-brown silty till which can be differentiated from the lower Richmond Till by the abundance of robust marine shell fragments (*Mercenaria* sp?) and coal clasts derived from a northwestward ice flow (Stea *et al.*, 2003). The Sugar Camp Till represents the surface till sheet throughout much of the map area (Maps 1 and 2).

River Inhabitants-Glaciolacustrine Unit 4

Overlying the Richmond Till at the Sugar Camp Quarry (Fig. 15) is a brown, silty clay (River Inhabitants-Glaciolacustrine Unit 4) which is also a widespread surficial deposit throughout the River

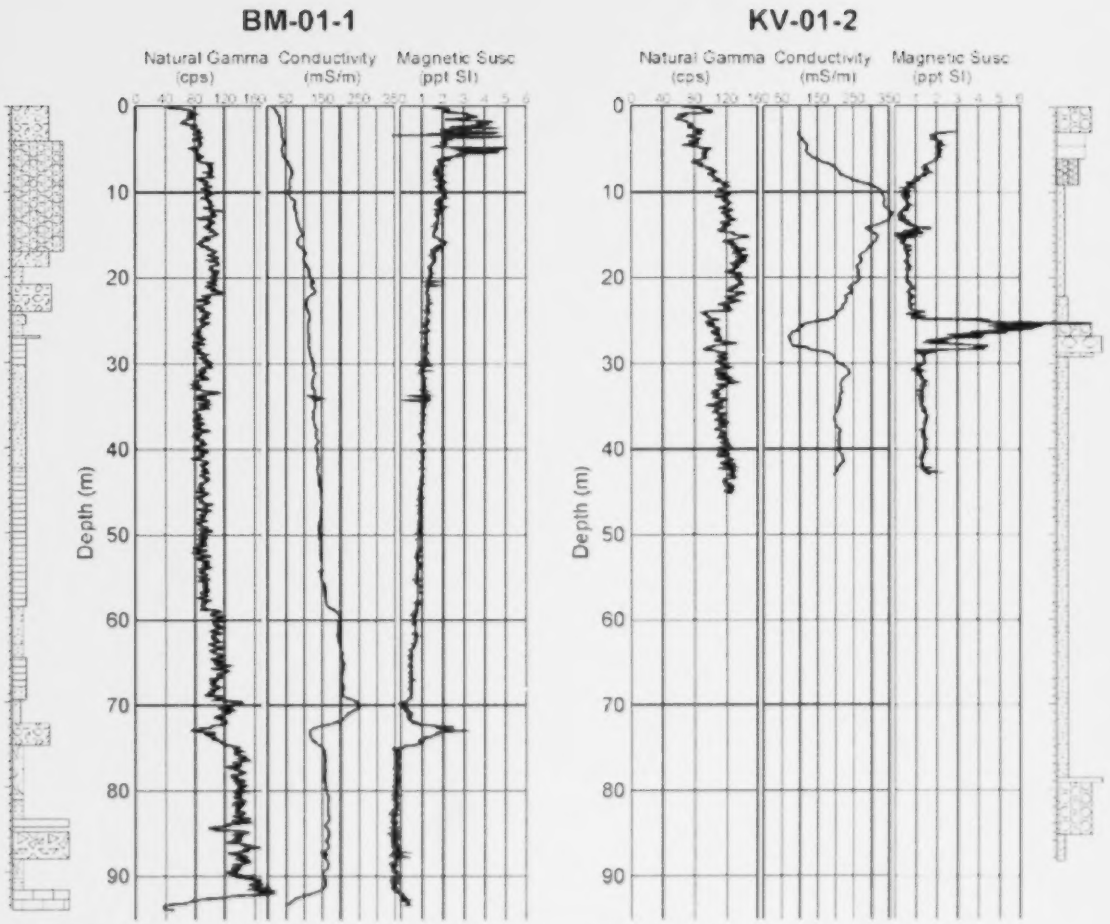

Figure 16. Geophysical and stratigraphic logs from TGI diamond-drill holes in the River Denys basin and River Inhabitants lowlands. Legend for the stratigraphic logs of the drillholes BM-01-1 and KV-01-2 is found in Figure 14.

Inhabitants lowlands (Fig. 1; Maps 1, 2). This fine-grained waterlain unit is interpreted as glacio-lacustrine, based on a lack of fossils and the lack of any other evidence of late marine submergence in the area, with the possible exception of the already noted marine/brackish deposits in KV-01-2.

Buried Glaciolacustrine and Glaciofluvial Deposits: Big Marsh Lowlands

Big Marsh Lowlands Stratigraphy

Based on previous seismic reflection testing (Pullan *et al.*, 2001), eight holes were drilled in the southwest part of the River Denys basin (Fig. 16) where surficial cover is commonly thick (30-100 m). Areas of special interest are the Big Marsh lowlands and the western margin of the River Denys basin. A stratigraphic profile from northwest to southeast across the Big Marsh lowlands was constructed using logs from drillholes URD-01, 2, MPR-01-1, and BM-01-1, 2, and 3 (Figs. 17, 18). The Big Brook quarry in the River Denys basin provides another reference section for the region, where radiocarbon dating of interglacial and interstadial organic beds provides temporal control for the lithostratigraphic units (Stea *et al.*, 2003). The surficial units in the Big Marsh area are described in the following sections from the base or bedrock contact to the top.

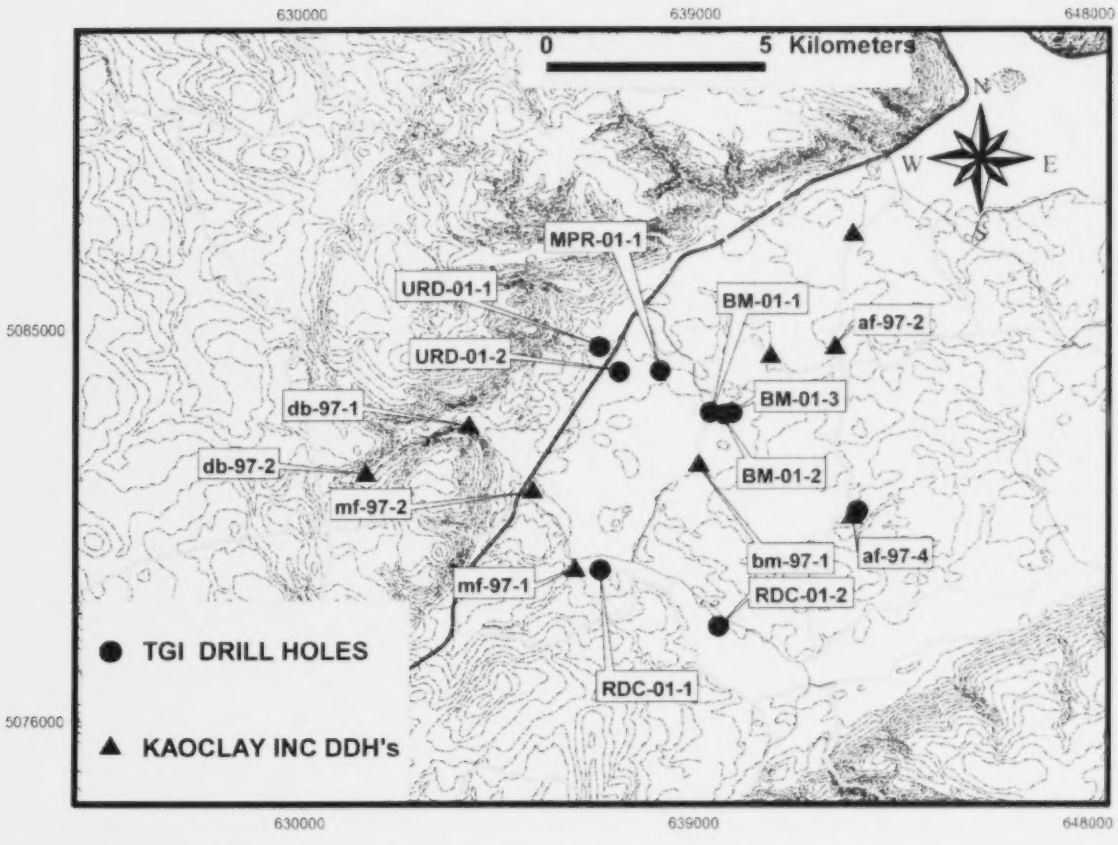

Figure 17. Location of reference sections, seismic lines and diamond-drill holes in the River Denys basin.

Bedrock and Breccias

Coarse-grained grey-white gypsum of the Windsor Group was encountered at the base of drillholes URD-01-1, MPR-01-1, BM-01-2, and BM-01-3 at depths of 80.8 m, 59.4 m, 56.3 m and 19.5 m, respectively (Fig. 18). Gypsum textures range from massive mosaic to slightly nodular, commonly grading into gypsum breccia infilled with grey clay. Steeply dipping bands of black-brown carbonate are also evident in the drill core. Hole BM-01-1 bottomed in grey-white limestone at 92.2 m. Lying above competent bedrock in the deeper part of the basin (BM-01-1) is a series of soft, alternating blue-grey and red-brown, strongly calcareous mudstones and breccias up to 20 m in thickness (interpreted as part of the Windsor Group).

Lower Till

Drag line trenches in the Big Brook gypsum quarry (Map 1) revealed a complex Quaternary stratigraphy, with an oxidized, greenish-grey silty till unit at the base, overlying the gypsum bedrock surface. Large spruce wood fragments were found embedded in the grey lower till, providing radiocarbon dates of >49,000 (GSC-3289) and >52,000 (GSC-3880) yr. B.P. (Grant, 1994; Stea *et al.*, 2003).

Overlying Carboniferous bedrock and breccia in the deepest part of the Big Marsh lowlands to the north (MPR-01-1, and BM-01-1, and 2; Fig. 18) is a package of coarse gravel, sand, boulders and red-brown silty diamicton interpreted as glacial till. Lower till thicknesses range from 0.3 m to 16.5 m, although the exact boundary of the lower till unit is

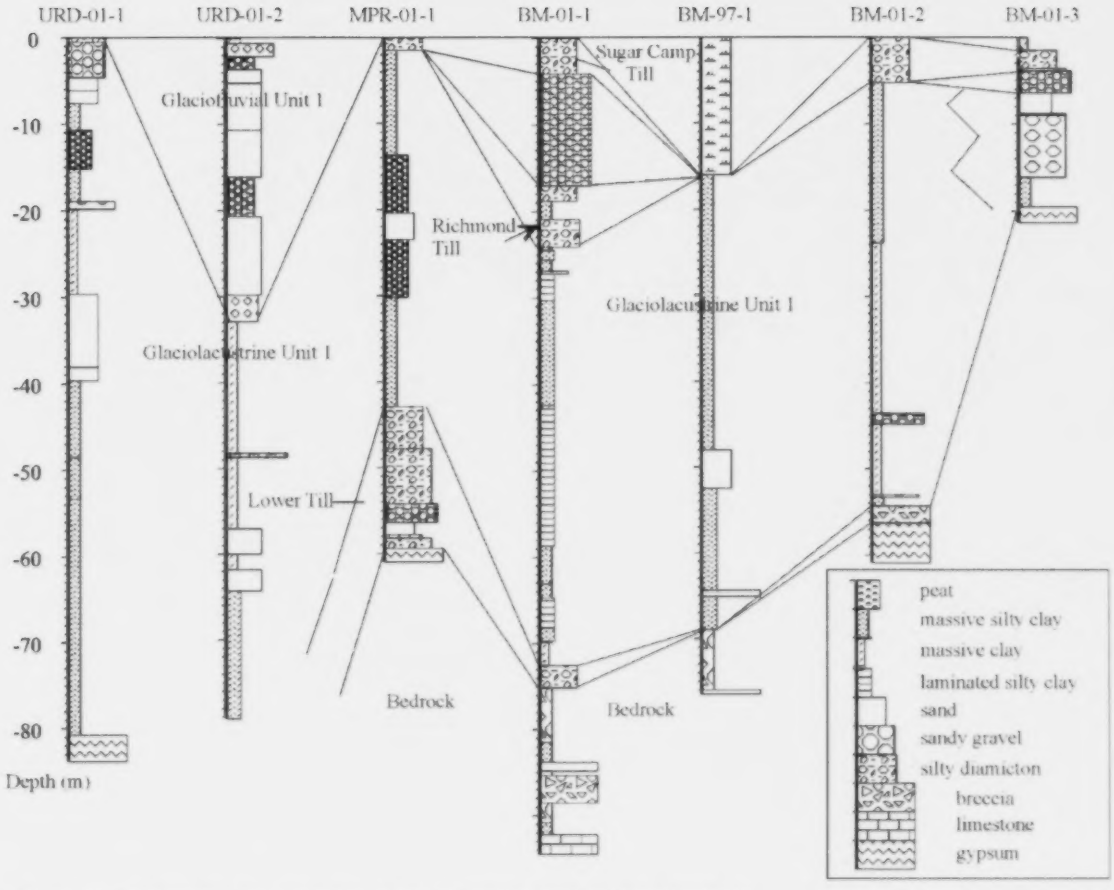

Figure 18. Stratigraphy and correlation of TGI drillholes in the Big Marsh lowlands.

sometimes difficult to establish. The till unit contains locally derived, angular clasts of white gypsum, black micritic limestone in a silty clay matrix, and also includes erratic grey-green mafic, and white, pink and green granitic pebbles and cobbles.

Interglacial Peat and Wood

D. G. Kelley in 1955 (cf. Grant, 1994) noted a thin organic seam sandwiched between two tills in the village of Whycocomagh (Fig. 1). Mott and Prest (1967) described the organic section as containing wood fragments, intercalated with grey organic silty clay and overlain by red silty till. A date of >44,000 yr. B.P.(GSC-290) was obtained from a piece of wood in the peat section. Another till-buried interglacial organic site was discovered during the TGI project near Ashfield (Fig. 17; Stea *et al.*, 2003).

River Denys Glaciolacustrine Unit 1

Overlying the bedrock/breccia and the lower till in the Big Marsh lowlands is a thick fine-grained deposit consisting of red-brown and grey-brown clay, silty clay, and sand with minor gravel beds (Fig. 18). This fine-grained unit ranges in thickness from 13 m to >40 m. Textures range from massive silty clay/clay to thinly laminated clay and silty clay, sometimes deformed by faults or folds. Dropstones are rare throughout the unit, but occur as well rounded pebbles of various lithologies, predominantly white quartz, grey and green

siltstone, and sandstone. Sandy beds range from fine- to coarse-grained and are generally thin (<2 cm). Rhythmically bedded zones are present, but rare. Magnetic susceptibility, natural gamma and conductivity geophysical logs (Fig. 16) demonstrate the inherent homogeneity of the clay unit, showing very little downhole variability in conductivity, natural gamma and magnetic susceptibility. Conductivity in the order of 70-200 mS/m in RD-GL1 is indicative of fresh-water glaciolacustrine sediments, based on a comparison of conductivity levels with marine muds in the Champlain sea where levels are as high as 1200 mS/m (Hyde and Hunter, 1998). Conductivity is a good indicator of pore water salinity (Hyde and Hunter, 1998).

Richmond and Sugar Camp Tills

A reference section for the Richmond and Sugar Camp tills is at Big Brook Quarry (Map; 1; Grant, 1994; Stea *et al.*, 2003). In the cored sections (Fig. 18) the Richmond Till is relatively thin, and contains a high percentage of dark grey-green mafic rocks, pink, green and white granites, and green and maroon siltstone derived largely from the Creignish Hills to the west. It is overlain by a younger unit, which occurs in all of the holes in this area, and is similar in texture and pebble assemblage, but generally more reddish-brown in colour and commonly containing shell fragments and coal clasts. It has been designated as the Sugar Camp Till based on a type section in the Sugar Camp Quarry to the south (Stea *et al.*, 2003). The contact between the two tills is not always obvious and may be gradational in nature. The total thickness of the two units together ranges from a veneer of ~1-5 m along the western edge of the basin to ~25 m in drillhole BM-01-1. The apparent absence of the Richmond Till in all holes except BM-01-1 implies post-depositional erosion of this unit over much of the basin.

River Denys Glaciofluvial Unit 1

The first 30 m of core URD-01-2 (Fig. 18) is a thick-bedded sand-dominated package including fine to coarse sand and some granules. This unit resembles sand units at Long Point, described earlier, including abundances of coal fragments. This sand-dominated unit likely originated as subaqueous outwash, perhaps derived from ice sheets retreating out of the River Denys basin to the southwest.

Seismic Stratigraphy of the Big Marsh Lowland

Continuous seismic reflection profiles were obtained in the Big Marsh lowland to connect the drillholes and obtain a three-dimensional view of the surficial units. Six seismic reflection lines were obtained providing a cross-section of the lowland across major topographic boundaries (Fig. 19).

Line 1

Line 1 (Fig. 20) crosses the westernmost part of the Big Marsh lowlands, just east of a fault that divides Carboniferous rocks of the River Denys basin from the Creignish Highland massif. Bedrock is shallow at the west end with multiple high-amplitude reflectors representing variations in lithification and brecciation (Stea and Pullan, 2001). A major fault discontinuity or erosional scarp is noted in the profile at the western end. Overlying the high-amplitude bedrock reflectors across the rest of the profile is a seismic unit characterized by few reflections and correlative with Glaciolacustrine Unit 1 (RD-GL1) in DDH URD-01-2 (Fig. 18). In the middle of RD-GL1 is a coarse-grained sand unit which produces a zone of high-amplitude discontinuous reflections, more prominent at the eastern end of the seismic line. The uppermost seismic unit consists of low-amplitude discontinuous reflections and forms a continuous cap on the sequence, correlative with the Sugar Camp Till in URD-01-1.

Line 2

Line 2 (Fig. 21) is an eastward continuation of Line 1 (Fig. 20). Near the middle of the line an erosional valley exceeds 150 m depth. Bedrock is again represented by high-amplitude reflectors and the overlying seismic unit is characterized by low-amplitude reflection energy correlative with the lower part of Glaciolacustrine Unit 1 in URD-01-2. A sequence of high-amplitude reflections

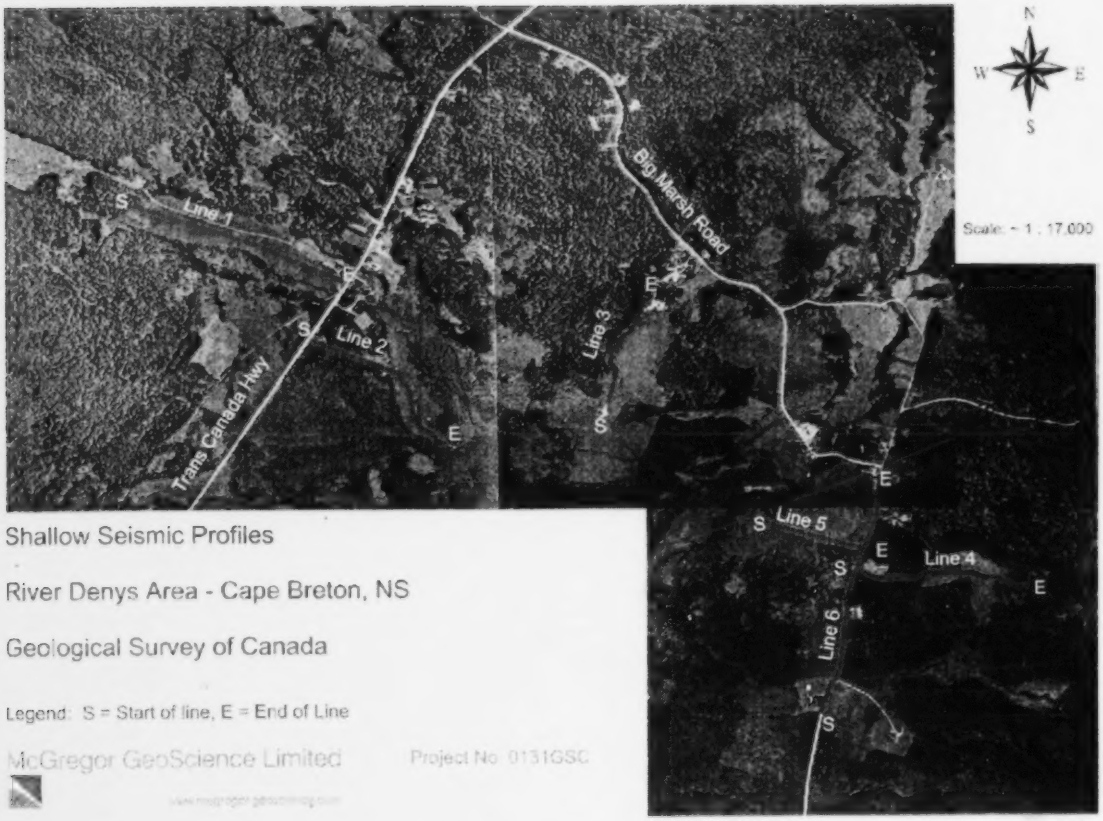

Figure 19. Air photographs of the locations of seismic lines 1-6 (see also Fig. 18).

subdivides Glaciolacustrine Unit 1, as in Line 1, and corresponds to sand beds in core URD-01-2. Unique to this line is a channel feature approximately 600 m wide and 40-50 m in depth indicated on the seismic sections by lapout of prominent reflections. This channel was filled with coarse sand and gravel (Glaciofluvial Unit 1) as evident on URD-01-2. These channel deposits can be traced to surface outwash deposits found along the northern edge of the River Denys basin (Fig. 1; Map 1).

Line 3

Line 3 (Fig. 22) is a N-S line which runs across a topographic high north of the Big Marsh lowlands. A series of south-dipping, high-amplitude reflections marks the gypsum bedrock surface, which was intersected by drillhole MR-01-1 at 60 m depth (Fig. 18). Lying above these bedrock reflections is a unit with high-amplitude reflections that pinch out downslope on a dipping bedrock surface. This seismic unit correlates with a lower till package in the drillhole, consisting of gravel interbedded with indurated till. Lying above this seismic package is a low-amplitude reflection seismic unit that relates to Glaciolacustrine Unit 1, with higher amplitude reflections corresponding to the coarse middle member of that unit showing up on the seismic profile. An upper seismic unit truncates some high-amplitude reflections from River Denys Glaciolacustrine Unit 1, which is a package of diamicton (till) beds collectively termed the Sugar Camp Till.

Line 4-5

Line 5 (Fig. 23) does not have a drillhole for

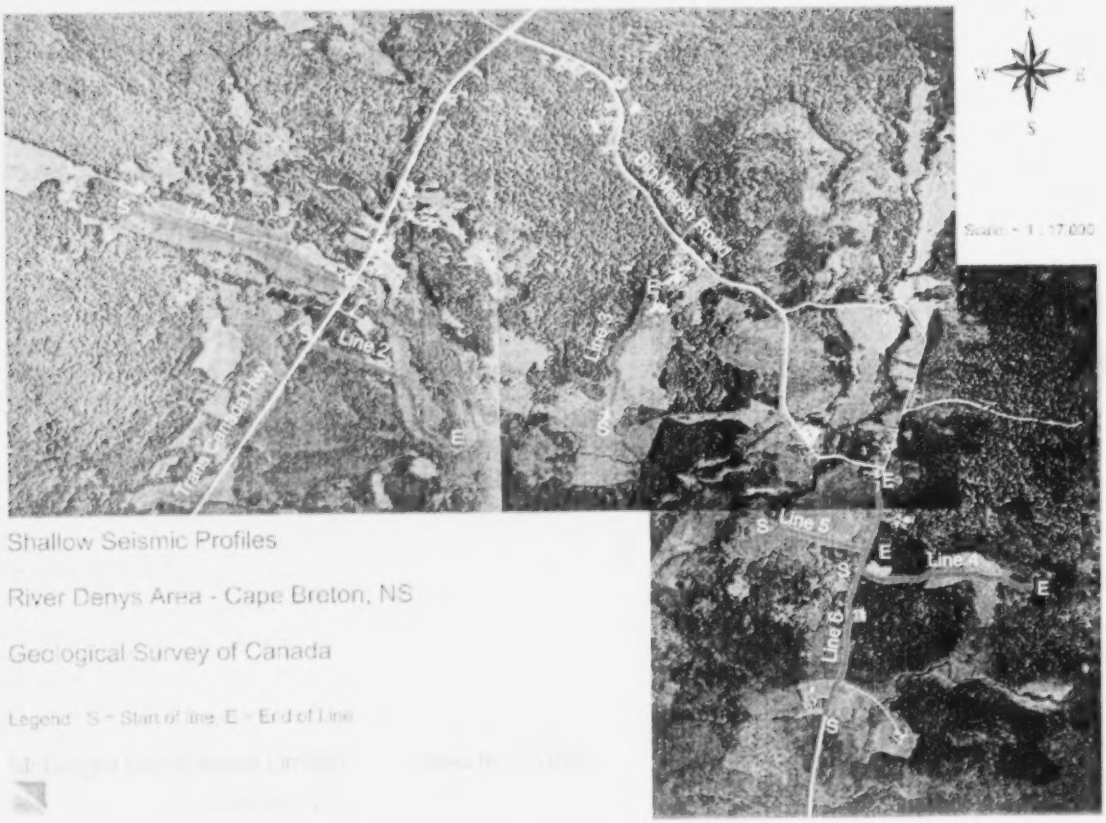

Figure 19. Air photographs of the locations of seismic lines 1-6 (see also Fig. 18).

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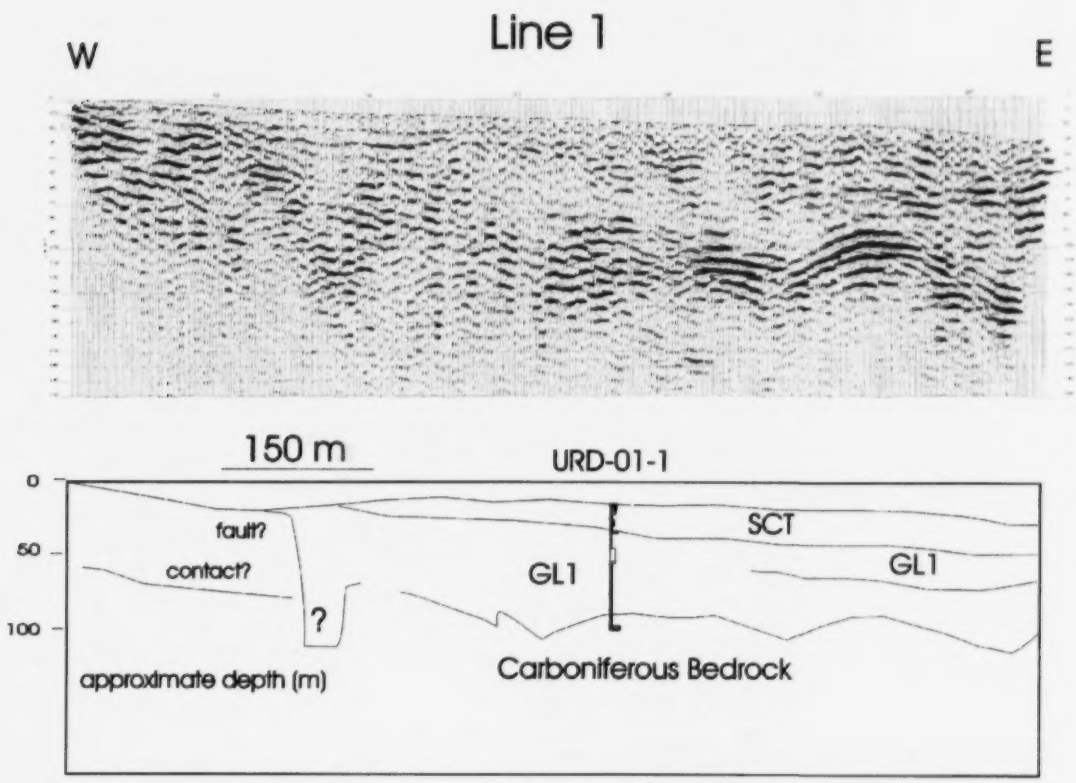

Figure 20. Seismic reflection profile and interpretation for Line 1, Big Marsh lowland. GL1 = Glaciolacustrine Unit 1, SCT = Sugar Camp Till.

control, and in general poor data were obtained. A bedrock reflection at the east end of the line is indicated at ~30-40 m depth. The line may skirt a prominent bedrock ledge seen on Line 6 (Fig. 24). On Line 4 two seismic units are indicated corresponding to Glaciolacustrine Unit 1 and Sugar Camp Till, intersected in nearby drillhole BM-01-1. Line 4 is the eastward continuation of Line 5 (Fig. 23), only farther south. A uniformly dipping, high-amplitude reflection that marks the bedrock surface rises from ~60 m at the west end of the line to within 20 m of the surface at the east end. About 450 m east from the start of Line 4 there is a marked discontinuity and change in dip of the bedrock reflection package, which may represent a fault. Above the bedrock surface the ~30-40 m thick reflection-free seismic unit is correlated to Glaciolacustrine Unit 1 in the borehole records. No reflection package marking coarser sediments in the middle of Glaciolacustrine Unit 1 is present in this seismic record. The uppermost seismic unit, characterized by low-reflection amplitudes, is interpreted as the surface till (Sugar Camp Till) unit, but may contain the earlier Richmond Till as well.

Line 6

The bedrock surface on this north-south line is represented by a north-sloping package of high-amplitude reflections that reach depths of ~100 m below surface (Fig. 24). Bedrock strata appear to dip to the south in the southern part of the line. At the northern end is a marked discontinuity where the bedrock surfaces rapidly. The change in bedrock topography is reflected by the transition from the flat Big Marsh lowland area to hills in the north. Above the bedrock reflections is a very thick, reflection-free seismic unit corresponding to Glaciolacustrine Unit 1 in core BM-01-1, without

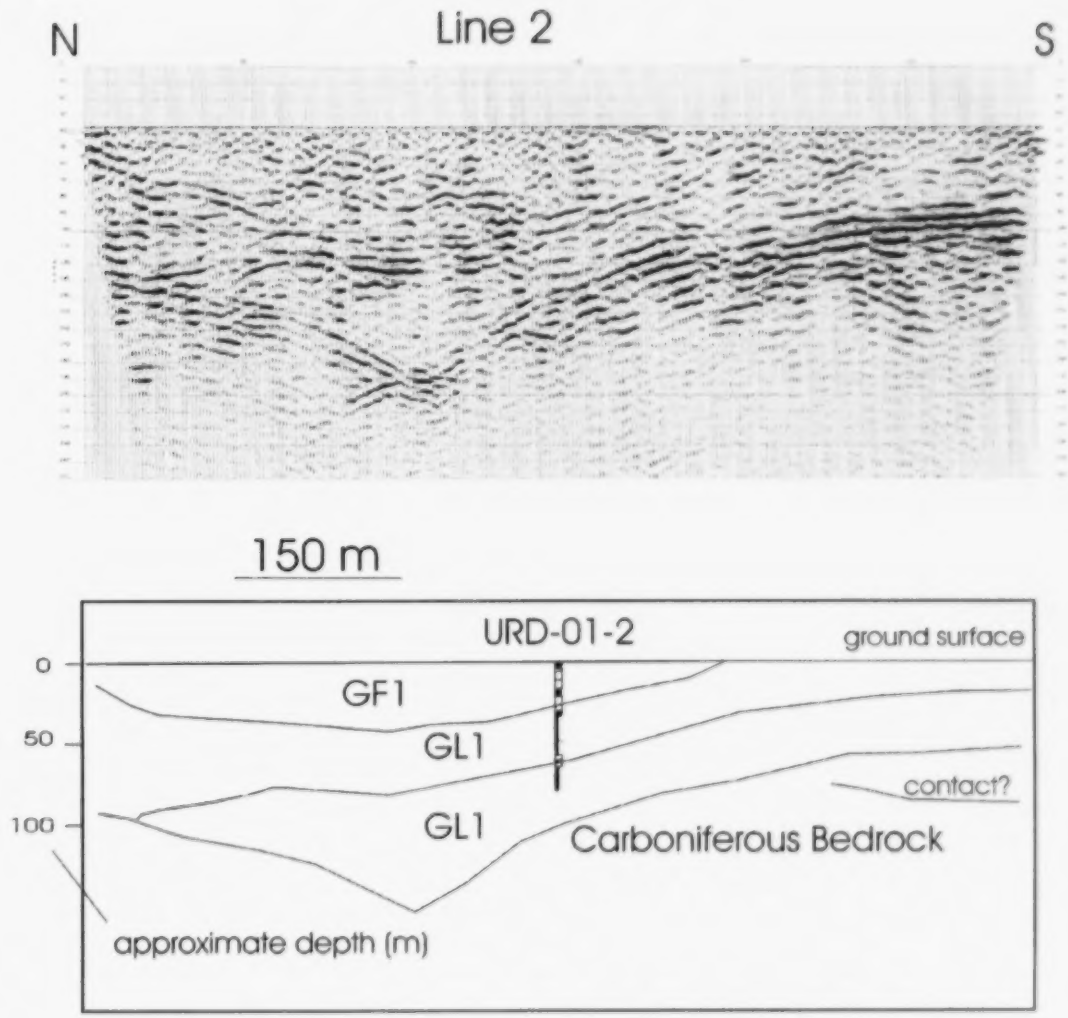

Figure 21. Seismic reflection profile and interpretation for Line 2, Big Marsh lowland. GF1 = Glaciofluvial Unit 1, GL1= Glaciolacustrine Unit 1.

the mid-unit, high-amplitude reflections found on the west side of the Big Marsh lowland. The uppermost seismic unit is correlative with two till packages separated by gravel and sand in borehole BM-01-1, but these units are not resolved in the record.

Summary of Big Marsh Stratigraphy and Formation of the Lowlands

Figure 25 is a schematic basin block diagram which summarizes the drillhole and seismic profile observations of the Big Marsh lowland. It is apparent that the River Denys basin is, at least in part, bounded by faults, especially on the northern margin with the Creignish Hills (Lynch and Brisson, 1996). The Big Marsh lowland is inset in the larger basin and it is hypothesized that this rectangular lowland is bounded by faults within the basin itself. Stea and Pullan (2001) suggested that much of the existing lowland/highland topography in Nova Scotia is a result of Mesozoic tectonics and basin exhumation rather than Tertiary erosion (cf. Goldthwait, 1924), based on deformed Cretaceous

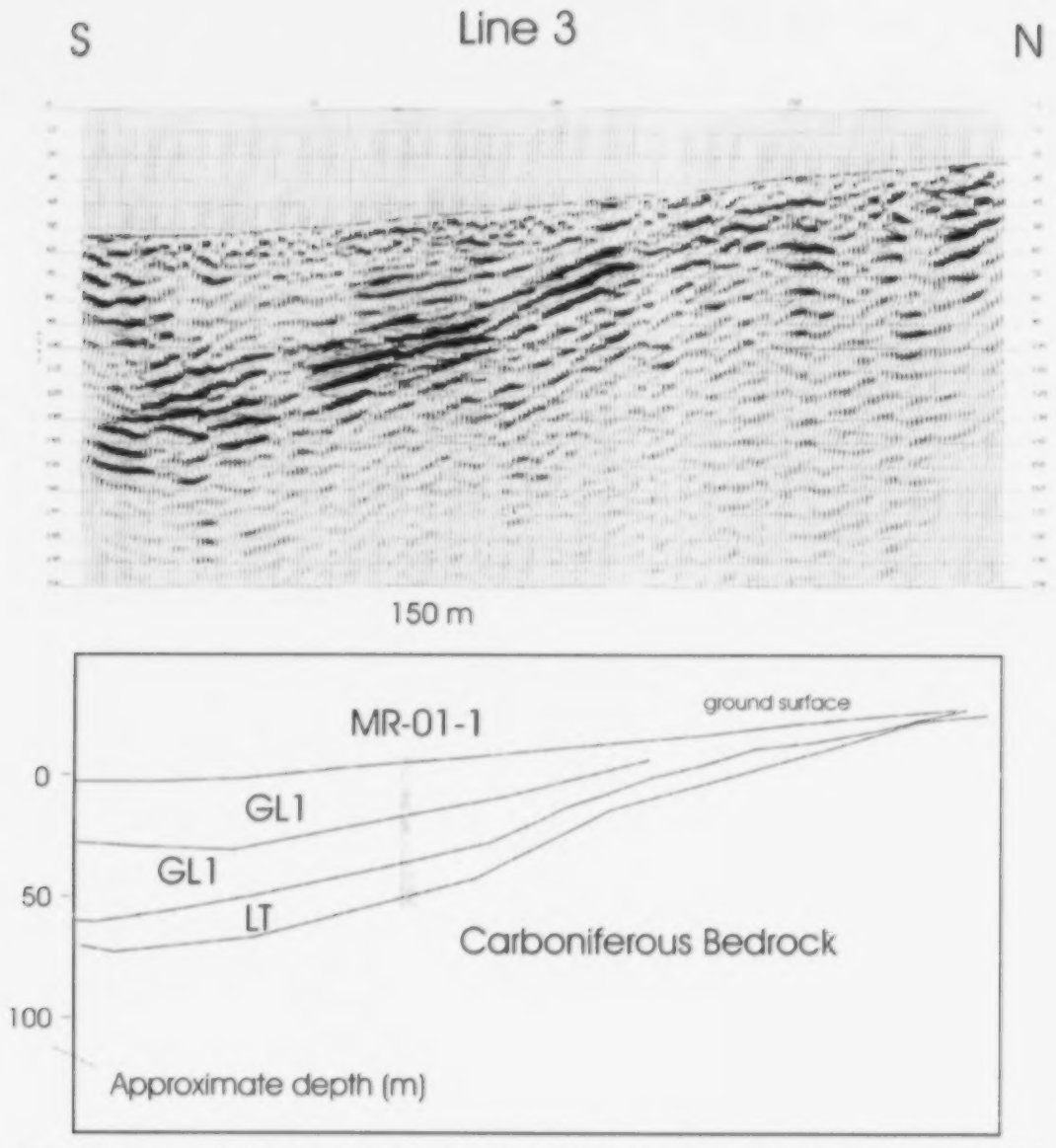

Figure 22. Seismic reflection profile and interpretation for Line 3, Big Marsh lowland. GL1 = Glaciolacustrine Unit 1, LT = lower till.

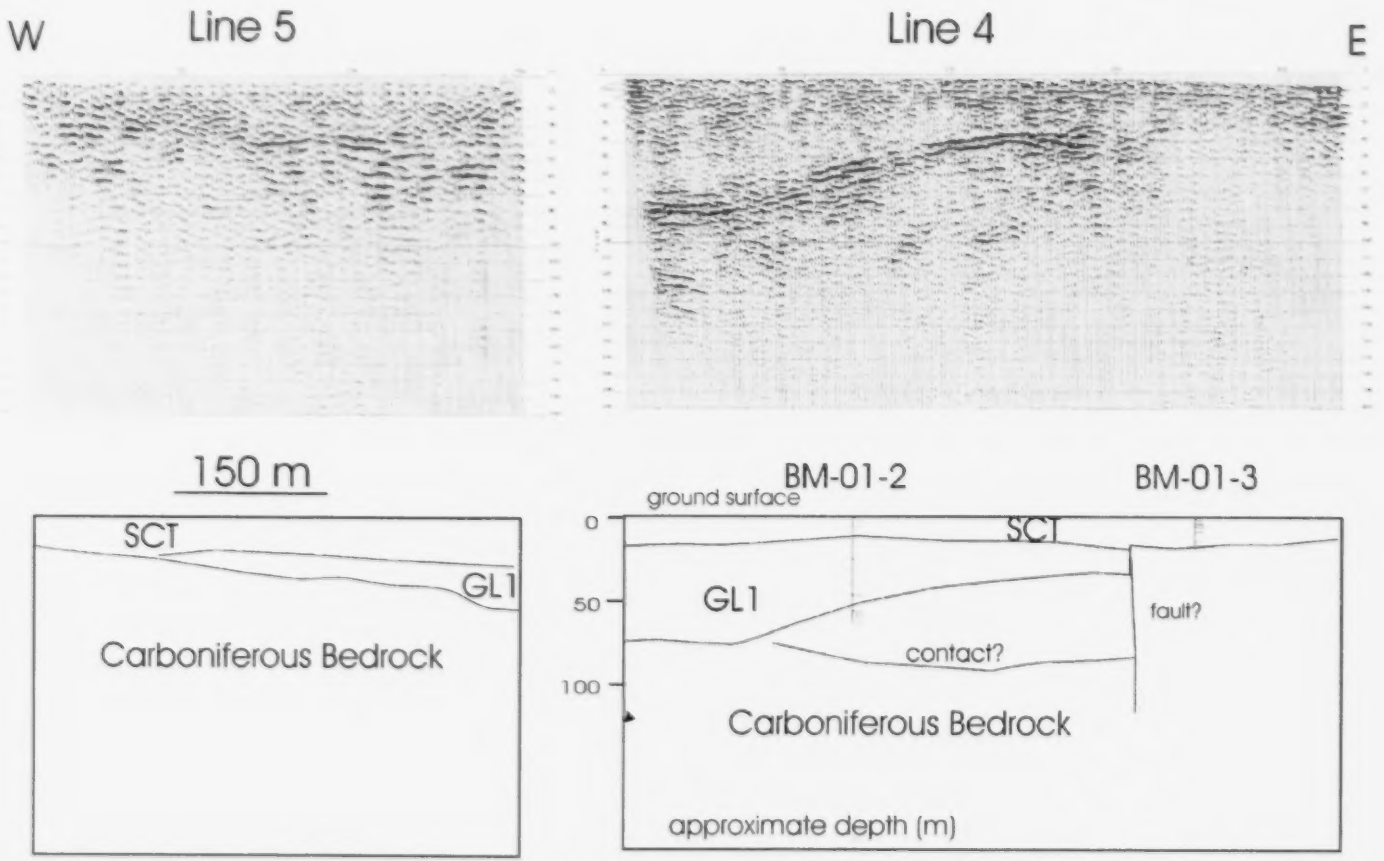

Figure 23. Seismic reflection profiles and interpretations for Lines 4-5, Big Marsh lowland. GL1= Glaciolacustrine Unit 1, SCT = Sugar Camp Till.

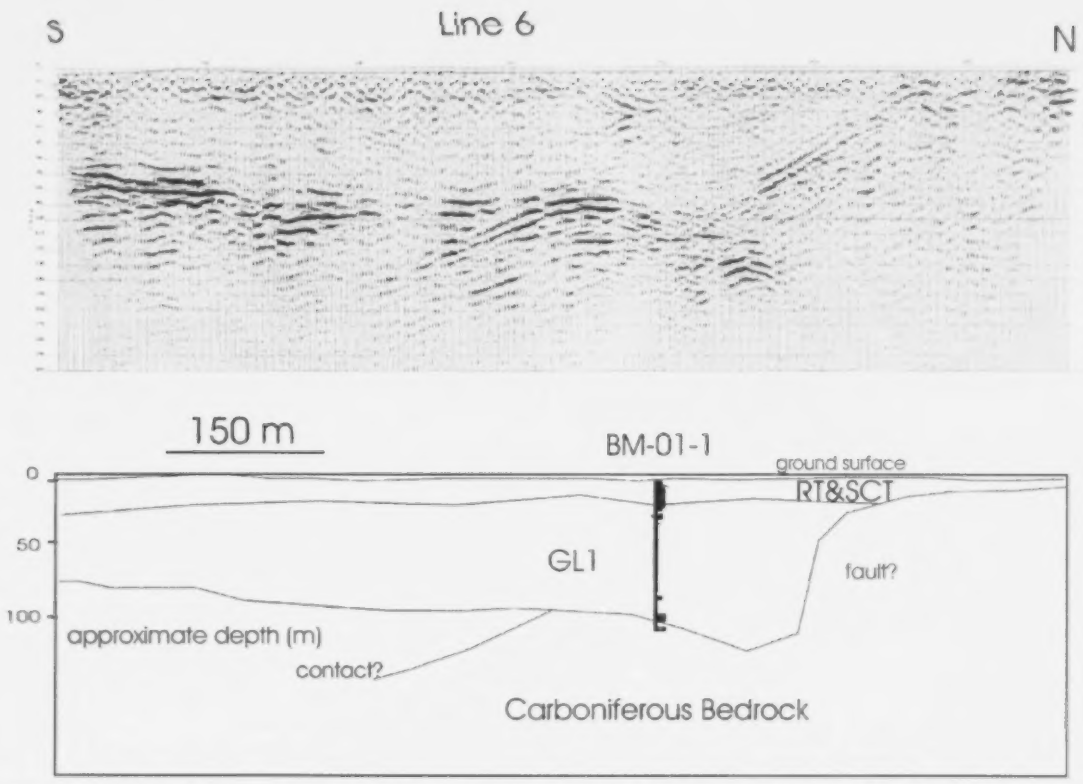

Figure 24. Seismic reflection profile and interpretation for Line 6, Big Marsh lowland. GL1= Glaciolacustrine Unit 1, RT = Richmond Till, SCT = Sugar Camp Till.

outliers preserved in fault grabens that define basin margins. One example of these faulted Cretaceous outliers is at Diogenes Brook or Glen Brook (DDH:db-97-2; Fig. 17) where ~60 m of unconsolidated silica sand and kaolinitic clay are preserved in a fault zone at elevations up to 120 m (Dickie, 1986). It was thought that other Cretaceous outliers might be present in the Big Marsh lowland using the model of the Musquodoboit Valley where the deposits cover ~40 square kilometres (Stea and Pullan, 2001). The absence of Cretaceous deposits suggests more intensive glacial and glacial meltwater erosion, as this basin is oriented parallel to a major northeastward ice flow (Grant, 1994). The rectangular shape of the Big Marsh plain and linear, cross-basin breaks in topography, however, suggest fault control of the topography. The seismic data reinforce this idea, with abrupt changes in bedrock topography apparent at the lowland margins. Although the drillhole data are not sufficient to prove this hypothesis, TGI drilling conducted to the west of the area revealed Triassic-Jurassic basalt (G. DeMont, personal communication, 2002). The presence of Mesozoic volcanics in the valley attests to relatively recent exhumation and the pattern of magnetic highs associated with the basalt suggests fault control.

Within the Big Marsh lowland fine-grained glaciolacustrine sediments make up most of the Quaternary basin fill, with an estimated 240 million tonnes of sediment. Along the base of the Creignish Hills a channel feature is filled with sand, and there are similar sand-filled channels in the obscured areas to the northwest where the Melford gypsum mine is located (F. Baechler, personal communication, 2003). A veneer of alluvial sediment (not shown on cross section) covers the glacial lake sediments.

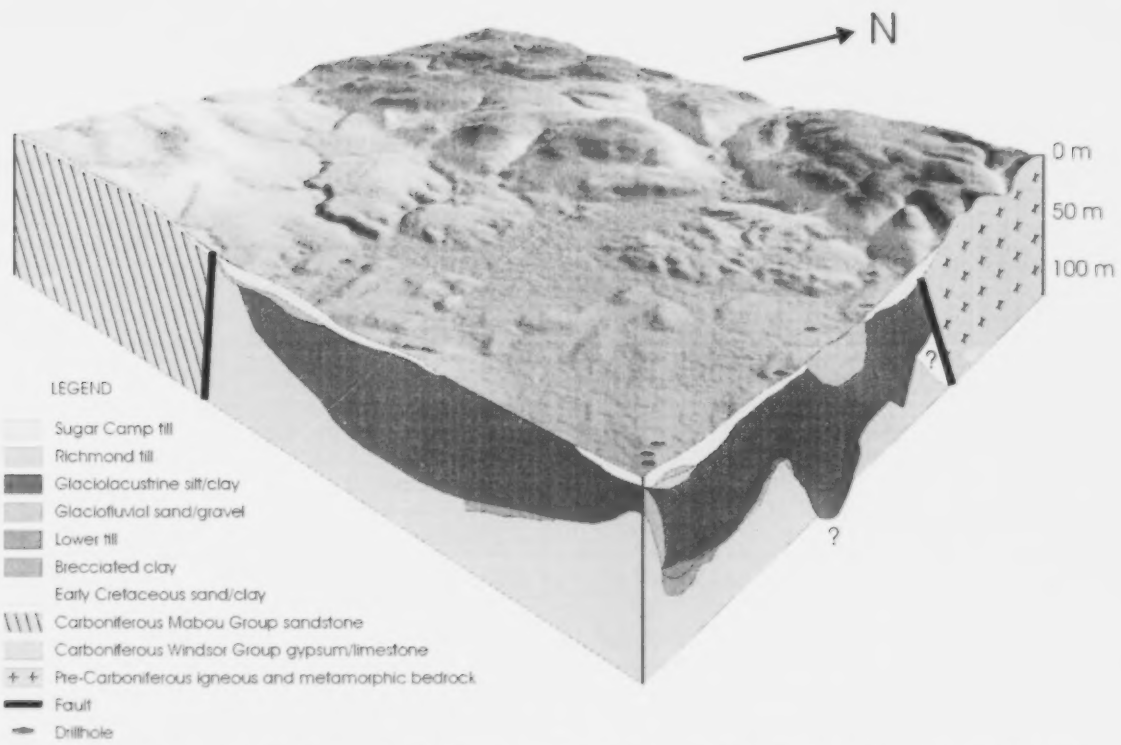

Figure 25. Schematic view of the topography and basin architecture of the Big Marsh lowlands, based on drillholes and seismic lines. Vertical exaggeration ~10X.

Origin and History of Clay and Sand Deposits in Cape Breton

During the Quaternary Period glaciers and ice sheets advanced and retreated over Cape Breton Island during 16 major glacial periods over 2 million years. The record of glaciations, however, spans only the last 200,000 years, including the penultimate glaciation (called the Illinoian) and the last major glaciation (the Wisconsinan; Stea *et al.*, 1992). Glacial lakes were impounded in the lowlands by glaciers in their development stages (ice advance glacial lakes) and by retreating glaciers (ice retreat glacial lakes). The topography of Cape Breton favours the development of glacial lakes because of narrow, highland-bordered outlets, easily blocked by highland ice.

Illinoian? Lower Till

It is likely that the lower till is related to a major glacial advance during the Illinoian glaciation or Marine Oxygen Isotope Stage 6 (MIS 6–230 ka), as evidence is lacking of soils and interglacial deposits predating the Sangamonian Interglaciation in eastern Canada (Stea *et al.*, 1992). At the Big Brook reference section (Stea *et al.*, 2003), however, wood contained within the lower till may have been eroded from older interglacial deposits (Yarmouthian?).

Glacier Lake Grant

After the Illinoian glacial advance, which deposited the lower till, the ice sheet probably receded out of the isostatically depressed Bras d'Or Lakes, leaving a series of interconnected basins either open to the

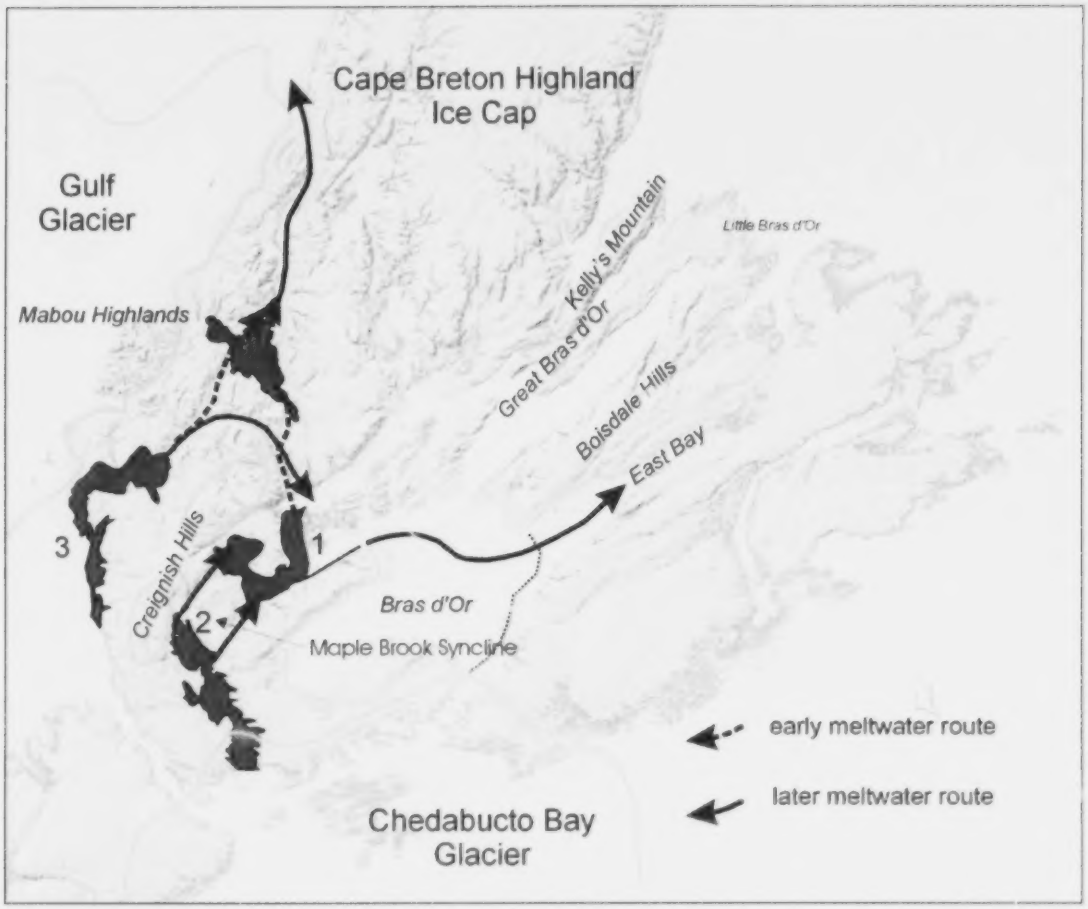

Figure 26. Development of ice-dammed glacial lakes in the lowlands of southwest Cape Breton Island when glaciers covered the Bras d'Or Lake and River Inhabitants outlets. Possible meltwater routings are shown by the arrows. Dotted arrows are early deglacial meltwater routings when ice was still in the Bras d'Or Lakes (dotted margin). 1: River Denys basin, 2: River Inhabitants lowlands, 3: Judique coastal plain and Moran basin. Glacial Lake Grant (Illinoian) probably occupied lowlands 1 and 2. Glacial Lake Cameron (Early Wisconsinan) also formed in lowlands 1 and 2. Glacial Lake Dawson (1 and 2) covered lowlands 1, 2 and 3. Shading on the DEM relates to regions below 30 m elevation.

ocean or, depending on the rate and mode of retreat, glacial lake basins (Fig. 26; cf. Grant, 1994). In the Sugar Camp Quarry, rhythmites interpreted as glaciolacustrine overlie the lower till and are conformably overlain by organic peat deposited during the last interglacial. They represent the formation of a glacial lake in the River Denys basin at the end of the Illinoian glaciation. The name Glacial Lake Grant is used to denote this water body, which would have been the oldest precursor of the Bras d'Or Lakes. It is named after Douglas Grant who did much to establish the paleogeography and chronology of ice marginal lakes in Cape Breton.

Sangamonian Interglaciation (MIS 5)

As the climate warmed and the glaciers receded, the Little Bras d'Or channel became ice free and Glacial Lake Grant drained through this lowest outlet (Shaw *et al.*, 2002b; Fig. 26). The reference locality of the interglacial deposits on Cape Breton

Island at East Bay, where three layers of organic beds are interbedded with fluvial gravel recording a progressively cooling climate from temperate to boreal/tundra conditions (Mott and Grant, 1985; deVernal *et al.*, 1986; Grant, 1994).

Glacial Lake Cameron

At Sugar Camp Quarry, rhythmites (RI-GL2) overlie Sangamon (MIS 5) organic beds. The rhythmites formed in a glacial lake that developed both in the River Denys and in the River Inhabitants lowlands. Grant (1994, p. 116) termed the lake "Glacial Lake Cameron". His evidence for the glacial lake in the Bras d'Or lowlands was primarily found in coastal sections along East Bay that feature interbedded marine and lacustrine organic clays, but Stea *et al.* (2002) interpret these sections as marine interglacial deposits relating to a higher sea level. Drillhole BM-01-1 in the River Denys lowlands shows an extended record of deposition of glaciolacustrine silty clay (RD-GL1; Fig. 18) just prior to the onset of a major glaciation. The development of a long-lived glacial lake in the River Denys lowlands, rimmed on three sides by highlands, would require an ice dam in the channels that drain the Bras d'Or Lakes or in the Bras d'Or itself, as suggested by Grant (1994). The lack of dropstones, and coarser ice proximal glaciolacustrine deposits throughout the basin, implies that the ice dam was some distance away and not in direct contact with the lake, a possibility if glacier expansion was first restricted to the Cape Breton Highlands as hypothesized by Grant (1994; Fig. 26).

The concomitant development of a glacial lake predating till deposits in the River Inhabitants lowland, as seen at the Sugar Camp section (Fig. 15), would have to be explained by an ice dam at the mouth of the River Inhabitants to the south. Glacio-isostatic depression of the basins would have presumably been muted during the development stages of these glaciers. This lake may not have developed at the same time as the lake in the River Denys lowlands in the north, but drainage routes for the southern Glacial Lake Cameron would have presumably been through the northern and southern gaps of the Maple Brook Syncline (Map 1; Fig. 26).

Caledonia Phase-Early Wisconsinan Glaciation (MIS 4)

The first major glacial advance in the Wisconsinan glaciation (Caledonia Phase) was toward the east-southeast, depositing a thick silty till termed the Richmond Till (Grant and King, 1984). The provenance and fabric of Richmond Till in the River Denys and the River Inhabitants lowlands imply an eastward flow (Stea *et al.*, 2003).

Stea *et al.* (1992), Grant (1994) and Stea *et al.* (1998) hypothesized that the Caledonia Phase was initiated by ice growth in the northern Appalachians, perhaps the White Mountains area of New England, an idea first suggested by Chalmers (1895). The extent and duration of the eastward flow event are in doubt, but it appears to have affected much of northern Nova Scotia and southeast New Brunswick (e.g. Rampton *et al.*, 1984; Stea and Finck, 1984) and there is some evidence that it may have affected west-central New Brunswick (Seaman, 2000). It may also be correlative with early eastward flow in northern New Brunswick (Parkhill and Doiron, 2003), which would certainly rule out a Laurentide source. It seems likely that if the Cape Breton Highlands were a site of glacierization, as postulated by Grant (1994), then the higher northern Appalachians would also have nucleated a large ice sheet.

Scotian Phase-Late Wisconsinan (MIS 2)

Sugar Camp Till exposed at the River Inhabitants and Sugar Camp Quarry sections can be related to a northwestward ice flow across the study area that crossed 300 m highlands. It represents a major glacier flow phase from a local ice divide in the offshore areas that was directed into the Cape Breton Channel, possibly to merge with Laurentide ice in the Laurentian Channel (Stea *et al.*, 1998; see description of ice flow events on Map 1).

Chignecto Phase-Late Wisconsinan

The last major glacier to develop over Cape Breton was situated over the Bras d'Or Lakes and southern Cape Breton (Grant, 1994). At several localities

southeastward striae of the Chignecto Phase (Grant, 1994; Phase E) postdate the strong northwestward flow (Scotian Phase). This last flow event is also linked to ice streams in the Cabot Strait and Laurentian Channel, which Josenhans and Lehman (1999) dated to ca. 13.5 ka (~16.2 CAL) (Stea *et al.*, 2003).

Glacial Lake Dawson (1 and 2)

The retreat of local Chignecto Phase glaciers in the Gulf of St. Lawrence and southwestern Cape Breton initiated the development of glacial lakes in the River Denys and River Inhabitants lowlands and Judique coastal plain. Shaw *et al.* (2003) describe an early marine incursion into the Bras d'Or Lakes, but it is not certain to what extent this early event would have inundated the lowlands. The lack of marine fossils and height of clay deposits (~ 40-70 m), and the lack of evidence of Late Wisconsinan raised marine features along the coast (Grant, 1994), all suggest that glacial lakes in the inland areas were held by ice dams rather than forming in isostatically depressed basins with marine incursion. Grant (1994) envisioned remnant ice in the Bras d'Or Lakes and in southern Cape Breton to explain ice-dammed lakes in these lowlands, but radiocarbon dating of Chase Pond, just south of the Bras d'Or Lakes, suggests an early deglaciation for this region (~13 ka; Mayle and Cwynar; Stea and Mott, 1998). It is possible that during an early phase of deglaciation when the Bras d'Or Lakes were still filled with ice some meltwater was routed from the River Denys basin through Lake Ainslie and the Cheticamp meltwater channel (Grant, 1994).

As the Bras d'Or was cleared of ice alternate routes were needed. Ice proximal glaciofluvial sediments near River Denys, interpreted as subaqueous outwash (RD-GF1; Fig. 21), suggest remnant ice caps over highland areas like the Creignish Hills, as does radiocarbon dating of upland lakes and bogs in the Creignish Hills and Cape Breton Highlands (Stea and Mott, 1998). Remnant ice remaining over Kellys Mountain, the Boisdale Hills and the adjacent St. Andrews Channel-Great Bras d'Or would have forced meltwater through a higher outlet at East Bay (Fig. 26). The elevation of the lake in the River Denys basin is uncertain, although there are glaciofluvial delta deposits near River Denys at ~30 m elevation (Stea and Feetham, 2003), which are at the elevation of a proposed outlet at East Bay. It would seem that former lake shorelines were ephemeral, and records of terraces and beaches have been overwritten by Holocene mass-wasting processes.

The surface clay units found in the Moran basin are unusually fine-grained and massive, but the lower facies contain coarse silty sediments, presumable derived from overflow and underflow meltwater plumes of a tidewater glacier front (Ashley, 1995). The clay-rich facies (Unit 5b) have a variable pebble content interpreted as dropstones, clasts that have been carried into a lake via floating shore ice and later dropped by melting. The sequence records a retreating glacier front in the basin itself and, later, farther south in the Gulf of St. Lawrence when a shallower lake formed as the normal Gulf drainage outlets were ice dammed. Glaciofluvial deposits in the Moran basin lack clinoform strata, suggesting that deltaic processes were responsible for the facies architecture and the glaciofluvial sediments were probably deposited subareally, during an ice re-advance after the lake had drained. During glacier retreat the Moran basin was periodically infilled with glaciofluvial (subareal outwash) deposits and fine-grained sediments were deposited in ice marginal lakes. This process was repeated during ice marginal re-advances. The abundance of tonalitic pebbles in the glaciofluvial deposits of the Moran basin almost certainly suggests erosion by glaciers to the north in the Mabou Highlands, source of the granitic pebbles (Barr and Macdonald, 1989). Lynn Baechler (personal communication, 2001) also noted abundant coal in ice contact deposits in the Lake Ainslie region, thought to be derived from a glacier to the north in the Gulf of St. Lawrence.

The fine-grained surface clay deposits in the Judique coastal plain (Unit 4) overlying the organic paleosol marker horizon are draped over topography, indicating subaqueous marine or lacustrine sedimentation. Marine deposition can be ruled out based on the known relative sea level (RSL) history of the region and the altitude of the clay deposits and associated deltas (+60 m; Fig. 7). After ~12 ka sea levels had dropped to between 50 and 100 m below present in the Gulf of St. Lawrence (Josenhans and Lehman, 1999; Shaw

et al., 2002a). In addition, the organic paleosol beneath the clay sediments implies a precipitous drop and rise in RSL not documented elsewhere in the Gulf. The open work gravel and interfingering rhythmites in the lower glaciolacustrine sediments (Unit 2) are characteristic of proximal subaqueous fan deposits and distal glacial lake-bottom sediments (Ashley, 1995).

In order to impound a body of water to a level of 60-70 m against the Creignish Hills, a glacier must have existed in the Gulf of St. Lawrence, as postulated by Grant (1994). Horizontal lamination and graded beds in the sand facies of the upper glaciolacustrine unit (Unit 4; Fig. 8) suggest deposition from suspension in a distal glacier setting, but the associated massive clay facies are puzzling. Lack of bedding suggests relatively shallow water but the extent and vertical range of these deposits make this unlikely. Stea and Mott (1998) identified two phases of glacial lake development termed Glacial Lake Dawson 1 and 2, using Grant's (1994) lake phase terminology. The glaciolacustrine deposits above (Unit 4-8) and below (Unit 2; Fig. 8) the peat/organic marker bed of Allerod age (11-12 ka) suggest that lakes formed first upon ice retreat and later by advancing ice.

The late-glacial sequence of events can be summarized as follows:

1. Ice retreat ca. 12-11.5 ka during the Allerod warm period and the development of Glacial Lake Dawson (1), perhaps localized in several inland basins including the Moran and Hawthorne basins.
2. Drainage of Glacial Lake Dawson (1) and ice retreat, with small ice caps localized in the emergent Gulf of St. Lawrence and on the Cape Breton Highlands. Biota migration onto the deglaciated landscape, ca. 11.5-10.8 ka.
3. Climate cooling and increasing storm intensity during the Younger Dryas climatic event (11-10 ka). Advance of a remnant ice cap in the Gulf of St. Lawrence, Cape Breton Highlands; formation of Glacial Lake Dawson (2) ca. 10.8-10.0 ka. (See Map 1 for colour inset of ice extent during the Younger Dryas climatic cooling).
4. Drainage of Glacial Lake Dawson (2). Climate amelioration after 10.0 ka.

Industrial and Hydrogeological Properties and Uses of Inverness County Clay, Sand and Gravel Deposits

Ceramic Clays of the Moran, Judique and Hawthorne Basins

Clay deposits outlined in this study are defined as secondary clays that were transported by water after formation by weathering processes, and deposited in glacial lakes (Ries and Keele, 1911). In ceramic use they are classified as earthenware or common clay, as they contain iron and other mineral impurities and fire at low temperatures between 900 and 1000°C (Rhodes, 2000). Fine-grained and homogenous earthenware clay deposits have been found in large areas of the various glacial lake basins identified in the study area and have potential as economic clay resources. The Moran basin has been evaluated in detail, but other areas such as River Denys basin and the Judique coastal plain (Fig. 1) also have economic potential, with clay deposits similar in composition and grain size. Indeed, at one time, both River Denys and Judique had brick manufacturing industries (Millard Wright, personal communication, 2003). Utilization of these clays as a resource material for ceramics and structural materials depends on a range of properties unique for each industry. For example, a brick manufacturer wants a large-volume source of moderately uniform clay that has a low shrinkage/swelling percentage, consistent firing colour, relatively low firing temperature, and good strength after firing. What follows is a description of the mineralogical and ceramic properties of the clay deposits, focusing on the Moran, Hawthorne and Judique areas, and interpretation of the results.

Grain Size and Mineralogy

Clay samples were taken from the Moran and Hawthorne basins and Judique coastal plain (Fig. 1) during the TGI project. The first suite of samples (Sites 55, 184, 185; Table 1) was obtained to compare clay properties between basins, whereas the last suite (Sites 55, 34, 31, 32; Table 1) was

Table 1. Clay samples from various basins in the study area analyzed for ceramic and hydrogeological properties. Basins: M = Moran basin; J = Judique coastal plain; H = Hawthorne basin; RD River Denys basin. Laboratories; M = Mission Clay Laboratories; H = Hocking College Ceramics Laboratory; NSCAD = Nova Scotia College of Art and Design; DU = Dalhousie University. Northing/easting coordinates-North American Datum 1927.

Site	Basin	Northing/Easting	Site Description	Lab
RS55/00	M	5093419/624541	massive clay (Unit 5b) clay plain	M/H/NSCAD
RS184/00	J	5081316/617321	massive clay (Unit 4b) clay plain	H/NSCAD
RS185/00	H	5092612/618723	massive clay-clay plain	H/NSCAD
RS31/00	M	5093362/624649	silty clay (unit 5c)	M
RS32/00	M	5093485/624572	clay (unit 5b)	M
RS34/00	M	5093570/624509	clay (unit 5b)	M
RS48/04	RD	5079574/645458	massive clay	DU

obtained for a preliminary look at the variation of ceramic properties within the Moran basin itself.

Four samples from two main facies in the Moran basin were analyzed for grain size distributions (Fig. 27). Samples from the main massive clay unit as described earlier (Unit 5b; Figs. 3, 4) contain between 25% and 40% clay, that is material less than 2 microns in grain size, with the rest made up of silt, skewed toward the finer grades of silt. Free quartz percentages are only between 6 and 13%, as determined by infrared spectroscopy (Table 2; Appendix 1), therefore the fine silt grades of all samples are probably made up of a substantial proportion of clay mineral agglomerates. This means that the clays are finer grained than the analyses indicate, as the clay minerals were not completely dispersed and disaggregated. Sample 34/00, from the middle of the Moran basin, is significantly more fine grained than the other two samples taken from Unit 5b. Sample 31/00, taken from Unit 5c (Fig. 4), was noticeably siltier in the field than the other three samples, with visible lenses of coarse silt. The grain size analysis shows a slight peak in the coarse silt range, but surprisingly, a similar grain size distribution overall to the other samples (Fig. 27).

The mineralogy of the first suite of clay samples was determined at the Hocking College Laboratory through differential thermal analysis according to a standard methodology described in Fowler (1972). Exothermic and endothermic reactions (heat loss and gain) produce positive and negative peaks on a curve that can be compared to standards and known clays. There is a strong endothermic peak at 500-600°C indicating dehydration of illite, probably the most abundant clay mineral (Fig. 28). The broad shoulders and secondary peaks on the DTA curve around 750°C indicate a mixture of clay minerals, perhaps chlorite, and minor carbonates (Bell *et al.*, 1978). What is immediately apparent is that all three samples from differing basins have a nearly identical mineralogy, as defined by the thermal reactions.

The results of the Mission Clay chemical analyses (Appendix 1) further verify that the clays are illitic, with potassium oxide percentages at 5%. The configuration of DTGA curves (derivative thermal gravimetric analysis; weight loss) are consistent with the predominance of illite (see Appendix 1). Iron is present in significant amounts and may be part of the illite structure with Mg (phengite) and as free iron oxide, responsible for the red colour of the clays. Mg and Ca, evident in the chemical analyses, are derived from local dolomitic bedrock as the clay exhibits moderate effervescence in dilute hydrochloric acid, and the DTGA curves show the evolution of carbon dioxide.

Table 2. Ceramic properties of Moran basin samples (Table 1) from Mission Clay Laboratories.

Sample Code	32/02	55/00	34/02	31/02
Total Carbon (%)	0.41	0.50	0.42	0.26
Organic Carbon (%)	0.15	0.18	0.15	0.11
Inorganic Carbon (%)	0.260	0.320	0.270	0.150
Sulphur (%)	0.000	0.000	0.000	0.000
Quartz (%)	10.4	13.8	6.5	12.3
Plastic Index	1.62	1.73	1.91	
Slake Time (min)	38	41	38	
Yield Pressure (psi)	125	125	107	
Penetrometer (ton/sq. ft.)	1.50	1.10	1.00	
Wet Shear (ton/sq. ft.)	0.65	0.45	0.50	
Lamination Tendency	Severe	Severe	Severe	
Fast Dry Experience	V. GOOD	V. GOOD	V. GOOD	
Carbon Effervescence	MODERATE	MODERATE	MODERATE	MODERATE
Water of Extrusion (%)	25.9	28.4	28.6	
Dry Shrinkage (%)	6.6	7.7	7.3	
Fired Shrinkage (%)	3.4	4.8	4.7	
Total Shrinkage (%)	10.0	12.5	12.0	
Total Dia. Shrinkage (%)	6.7	7.8	7.8	
Absorption (%)	8.7	6.8	7.5	
Dry Modulus (psi)	624	619	701	
Fired Modulus (psi)	5236	7136	7193	
Aged Modulus (psi)	3795	6148	3867	
Aged Loss (%)	27.5	13.8	46.2	
Ignition Loss (%)	6.1	6.6	6.5	
Sag in 32n=s of In.	2	2	2	
Core/46 mm (%)	27	58	42	
Fired Temp. (°F)	1840	1840	1840	
Colour of Core	BLACK	BLACK	BLACK	
Colour of Bar	ORANGE	ORANGE	ORANGE	
Fire Check Key	16	16	16	

Ceramic Properties

Ceramic properties of the clay samples (Table 1) are given in Tables 2, 3 and 4. Initial testing was done on samples from the various clay basins on the west coast of Cape Breton (Tables 2, 3 and 4; Fig. 1). NASCAD (Nova Scotia College of Art and Design) student testing was conducted over a range of temperatures, from Cone 08 (945° C) to Cone 6 (1190° C; Table 3). Table 2 is a summary of the testing results of the Moran basin samples done at the Mission Clay Laboratories.

Plasticity is the property of clay that allows it to be shaped and hold its shape. In the case of pottery use, clay plasticity is often defined subjectively by the potter, who evaluates its response on the throwing wheel. As part of the project clay samples and a questionnaire were sent to potters in Nova Scotia and Ontario (Appendix 3). These artisans all rated the plasticity or "throwability" of the clay between 8 (very good) and 10 (excellent). The "water of plasticity" is the percent of water necessary to develop optimum plasticity in clay, and is an

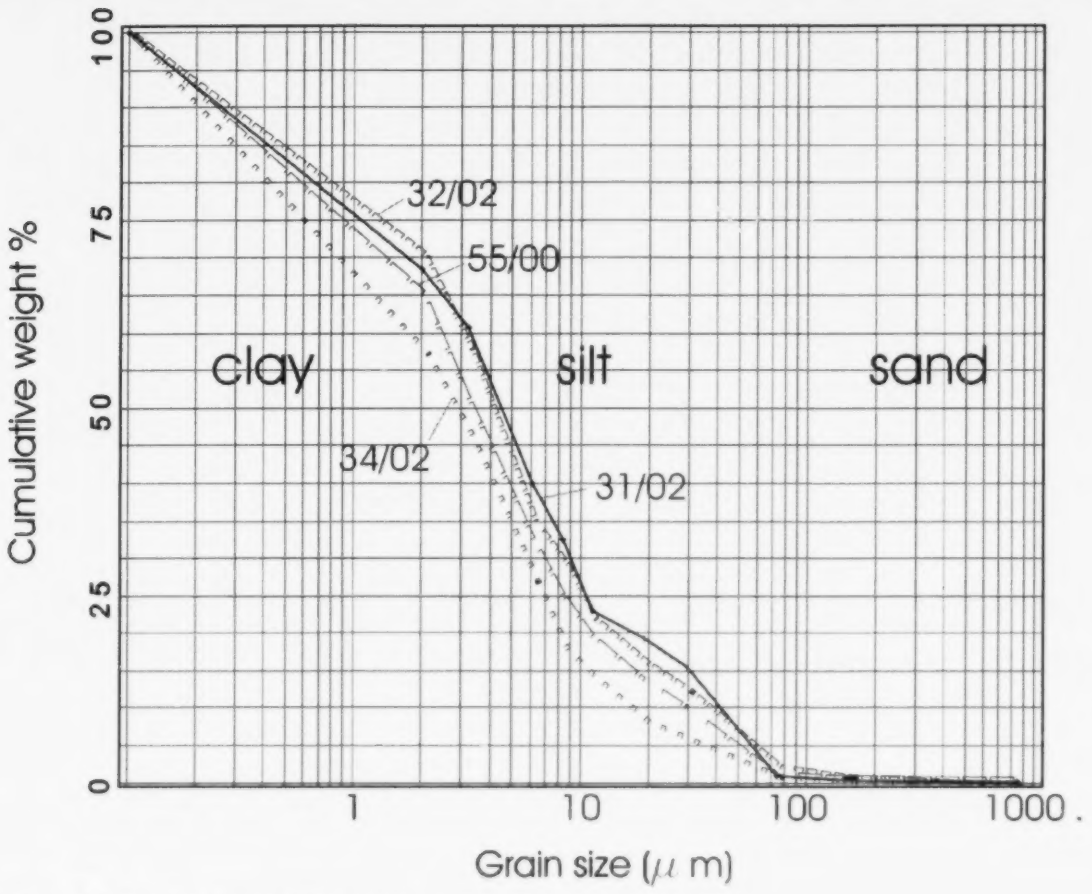

Figure 27. Grain size curves for clay samples from the Moran basin (Table 1).

indicator of the particle size of the clay: the finer the particle size the more plastic the clay. Water of plasticity levels (30-34%) are an indication of the very fine grain size of the Moran and Hawthorne basin samples (Table 3).

Dry shrinkage (DR) represents the size ratio before and after drying, whereas the total shrinkage (TS) represents the additional form changes after firing to vitrification temperatures as presented in Tables 2-4. Modulus of rupture (MOR) is a measure of tensile strength in psi. Absorption or vitrification (V) is a measure of pore space reduction during firing. It is also called "boil absorption" and is measured by boiling a fired bar for two hours and measuring the weight gain of absorbed water.

The data show strikingly similar test results from the separate glacial lake basins defined on the map. Dry shrinkage values vary from 5-9%, within the range of values cited for illitic clays (Grim, 1962). Drying defects such as warping and cracking were not observed in the laboratories. Total shrinkage values vary from 9.2% to 12 % for all the clay samples when fired to optimal vitrification temperatures of about Cone 04. Differences in shrinkage properties for samples from different basins (i.e. samples 184, 185, 55; Table 4) are less than observed for the same samples between different labs (i.e. sample 55, Tables 2-4). The lab differences can be explained by the slightly differing firing temperatures used and natural variability between samples. Optimum

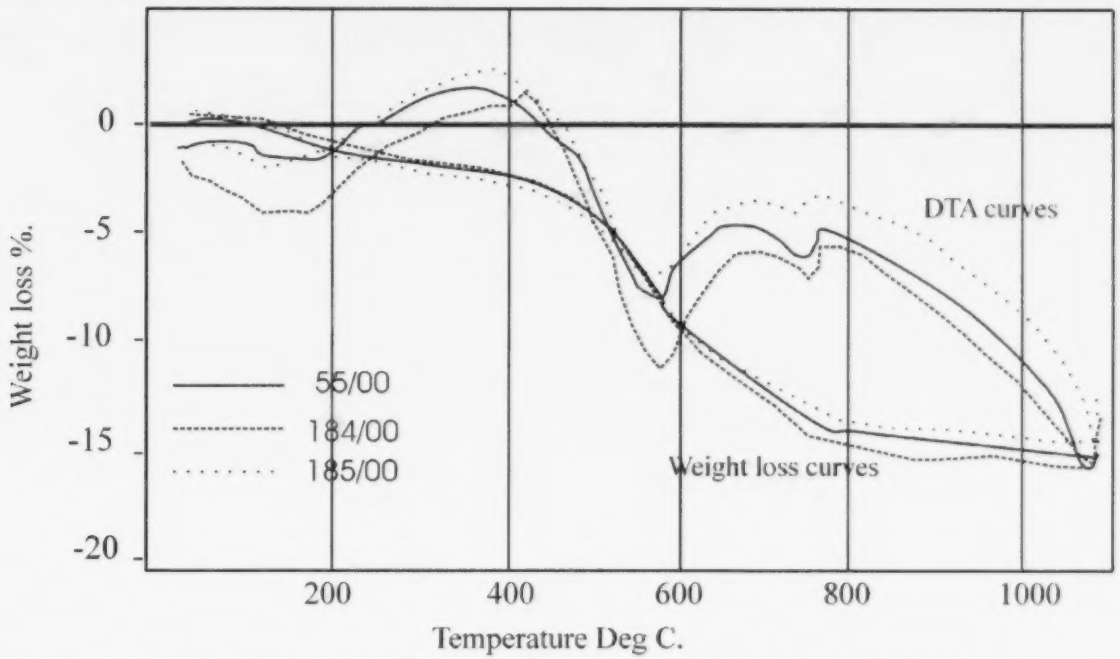

Figure 28. Differential Thermal Analyses (DTA) curves and weight loss curves for clay samples from the Moran, Hawthorne and Judique basins.

firing temperatures of 1027°C (1880°F) were determined for the Hocking College samples (Table 1) using a thermal gradient furnace. Optimum firing temperatures of 1005°C (1840°F) were determined by the Mission Clay technicians (Table 2) using thermal test curves made during the firing of the samples (Appendix 1).

Dry MOR values for the intra basin samples done by Hocking College range between 439 and 550 psi with the best results from the Moran basin sample 55 (Table 4). A similar yet higher range of values (619-701 psi) were obtained from the Mission Clay laboratory (Table 2). Fired MOR values were substantially higher in the Mission Clay laboratory analyses (5326-7193 psi; Table 2), perhaps reflecting the use of a more precise firing temperature. The Mission clay lab also measured strengths after an artificial aging process that involved boiling in a pressure cooker and rapid cooling before the subsequent test. The reduction of MOR was substantial in samples 34 and 32 and negligible in sample 55 (Table 2). The Moran Basin clays all showed a strong tendency to laminate during extrusion, that is the centre of the extruded column of clay tended to move faster than the sides, creating strong shear stresses and planar zones of weakness. This explains the reduction in aged MOR in some samples. Lamination is more likely in illitic clays with larger clay particles and can be reduced by adding granular components (Grim, 1962).

Potential Uses

Pottery and Clay Slip

In a much used handbook for potters entitled *Clay and Glazes for the Potter*, Rhodes (2000) provides these data for the "ideal" earthenware clay: good plasticity (not too sticky), fires to a terracotta colour at Cone 04, total shrinkage 11%, and absorption 6%.

Site 55/00 from the Moran basin was sampled and analyzed by three laboratories and produced a mean total shrinkage of 11% and an absorption of 7%, nearly identical to the "ideal" clay as described by Rhodes (2000), and well within parameters of other commonly used commercial earthenware clays. Samples from the other clay basins showed similar and only slightly less desirable results. The Moran basin clay is also very similar in texture and

Table 3. Ceramic properties of clay samples from NASCAD laboratory.

Clay test type	RS-185/00	RS-55/00	Clay-Lantz
Plasticity	Very good	Very good	Very good
Water of plasticity (%)	28	34	33
Dry shrinkage (%)	5	8.7	5.2
Total shrinkage- 08 (%)	7.1	5.1	6.3
Absorption -08 (%)	14.3	10.3	14.4
Total shrinkage-04 (%)	10.1	10.7	10.8
Absorption -04 (%)	8.0	6.8	6.3
Total shrinkage-1 (%)	14.0	15.9	13.4
Absorption-1 (%)	0.1	0.8	0.2
Total shrinkage -6 (%)	-	-	-
Absorption -6 (%)	-	-	-

firing properties to the Lantz clay, also from Nova Scotia, which is used commercially for bricks and as a pottery clay (Table 3).

Six potters from Ontario and Nova Scotia were sent samples of the Moran basin clay and a questionnaire (Appendix 3). The consensus of the potters was that the clay was excellent for throwing, did not scum or effloresce when fired, was good for a variety of glazes, had a nice colour and burnished well. A negative aspect of the raw clay was the content of tiny stones, which when not detected on the wheel created some imperfections and cracks in the final product. The high plasticity of the clay also may require some filler or "grog" for larger pieces or sculptural work to reduce shrinkage and facilitate drying.

Differing glazes were tested with the Moran clay, including a terra sigillata made from the clay itself, white slip, leadless alkali borosilicate glazes, and a lithium-fluxed matt glaze. The slip was applied to leather-hard tiles and pots, and bisque-fired to Cone 08, then fired to Cone 04. The extremely fine grain size of the Moran clay is ideal for the production of a slip glaze, which is produced by diluting and deflocculating the clay to a specific gravity of ~1.2 (Rhodes, 2000). Fired Moran clay yielded acceptable terra sigillata glazes both from slips made from the clay itself and from commercially available clay. In order to extend the varieties of glaze colours available from red firing clays, it is common to use them over white slips. A transparent glaze will give a different colour over a previously applied white slip, increasing the variety of colour possibilities. Halifax White Slip (Table 5) was applied to the plastic clay at wet and leather-hard stages. The Moran clay accepted the glaze without slumping and after drying showed no evidence of shearing and cracking.

The most important criterion for earthenware glazes used for pottery is their ability to avoid shivering or crazing (cracking). Roxy's Clear glaze (Table 5) was applied to Moran clay without stains or metals, adding 6% copper carbonate. Glaze application was trouble-free and the fired glazes were free of any glaze faults like blistering, pin-holing, scumming and crazing. There also appears to be no delayed crazing six months after firing. John's Blue (Table 5), a soda-rich glaze developed in the near east, was also tested on the Moran clays. A high percentage of residual salts can cause

Table 4. Ceramic properties of clay samples from Hocking College.

Clay test type	RS-185/00	RS-55/00	RS-184/00
Moisture (%)	2.0	6.6	3.0
Water of extrusion(%)	21.5	20.8	21.2
Dry shrinkage %	5.52	4.98	4.52
Total shrinkage (fired +dry%) Cone-04	10.14	9.98	9.23
Absorption (%)	8.3	7.5	7.7
Porosity (%)	17.8	16.1	16.6
Dry MOR (psi)	439.2	550.2	488.3
Fired MOR (psi)	2975.3	3474.4	3174
Density (g/cm^3)	2.1	2.18	2.17

scumming of the fired glaze using this type of glaze. The Moran clay accepted this glaze without problems. Finally, the durable matte glaze Gloria's Ace (Table 5) was tested on the Moran clay and produced a defect-free surface.

Brick and Tile

The properties of the Moran clay that are important for brick and tile manufacture are summarized in the Mission Clay report in Appendix 1. In summary, the positive aspects of the Moran clay include its extremely low firing temperature, excellent strengths, low boil absorption and low alkali content. Negative aspects are a very fine grain size and high plasticity. These deleterious properties can be overcome with the addition of a suitable filler to reduce the dry shrinkage, lamination tendency and demand for water of extrusion. It must also be noted that only the clay-rich facies of the Moran basin (Unit 5b; Fig. 1) was tested, under the assumption that the coarser facies were too silty for brick making. This was a false assumption, as the grain size of the siltier facies (Unit 5c; Figs. 3, 4) was much closer to the massive pottery clay facies than presumed, and these facies may be suitable for brick making. These silty facies should be tested in order fully evaluate the potential of the Moran basin. Nevertheless, the homogeneity of the clay-rich unit will allow for consistent mixing with other clays and silica fluxes (grog) for modification of properties to suit detailed needs (Bell *et al.*, 1978).

River Denys Lowland Clay Deposits

As stated earlier, clay deposits in adjacent lowland basins of western Cape Breton Island have very similar ceramic properties. The surface clay deposits of the River Denys lowlands (Fig. 1) were not sampled or analyzed in this study, but data are available from publications by Ries and Keele (1911) and Gouthro (1989). Based on surface mapping these clays are massive and fine grained, texturally similar to the Moran clay, and were probably formed in the same environment from similar glacial source materials. These clay deposits were made into brick at a plant near River Denys, which provided bricks for the construction of the Sydney steel plant at the turn of the Twentieth Century (Ries and Keele, 1911). Data from Ries and Keele (1911) show that the deposit was fine grained (90% below 200 mesh), had relatively high dry tensile strength, and fired at low temperatures (Cone 03; 1080°C) with fired shrinkage at 5% and absorption at 7.6%. Additional data on the River Denys deposits obtained by Gouthro (1989) are available in Appendix 4.

Landfill Liners and Caps

Clays, because of their fine-grained, plastic nature,

Table 5. Glaze varieties tested with the Moran clay (Site 55/00; Table 1).

Halifax White Slip	%
Ball Clay	40
Talc	30
Nepheline synenite	10
EPK (kaolin)	5
Ferro frit 3124	5
Flint	10
Roxy's Clear	
Ferro frit 3134	25
Ferro frit 3195	15
Ferro frit 3249	35
EPK (kaolin)	25
John's Blue	
Ferro frit 3110	76.3
Gherstley borate	5.7
EPK (kaolin)	7.5
Flint	10
CMC gum	0.5
Copper carbonate	6
Gloria's Ace/Jackeeze Matt	
Gherstley borate	35
Flint	41
Lithium carbonate	10
Nepheline syenite	5
N.S. EPK (kaolin)	5
Zircopax	8

have significant application as natural impermeable seals for civil engineering or geotechnical projects, such as waste facility liners, cover seals and sewage lagoon liners. Current environmental standards demand high impermeability and long term stability for the liner material. The purpose of compacted clay in landfill bottom liners is to minimize contaminant transport from the landfill to an underlying groundwater system. Contaminant transport through a bottom liner can occur via leakage, diffusion and dispersion. When the leakage is relatively slow (i.e. the clay is relatively impermeable), dispersion becomes negligible and diffusion tends to dominate the contaminant transport process. Diffusive transport tends to be a very slow process compared to leakage, and hence is the reason that relatively impermeable clay (i.e. a clay with low hydraulic conductivity) is used as a bottom liner system component in many landfills.

The hydraulic conductivity of a soil will depend on its grain size, structure, mineralogy and chemical properties. Basic geotechnical properties, such as plastic limits and liquid limits, assist in providing information on a clay's chemical and mineralogical properties as well as information on the potential for low hydraulic conductivity (i.e. low leakage). A more direct measure of the relative impermeability of a clay is hydraulic conductivity testing. For most regulatory environments in North America, the minimum hydraulic conductivity specified is 1×10^{-9} m/s. Clays with hydraulic conductivities lower than this (1×10^{-10} m/s) are preferred since this promotes less leakage and potentially slower diffusion. The Nova Scotia Department of Environment (1997) details the design, construction and maintenance requirements for municipal solid-waste landfills.

In order to establish the potential of using this clay material as a landfill bottom liner material, two samples of the clay from the Moran basin (55/00; Table 1) and River Denys basin (48/04; Table 1) were sent to Dalhousie University's geotechnical laboratories to establish basic hydrogeological and engineering characteristics. Table 6 provides a summary of these results. Tests were performed generally following standard methods from the American Society For Testing and Materials (ASTM; see lab methods).

These preliminary results indicate that the clay material has very promising potential for use as a landfill bottom liner system (or cover material) due to low permeabilities and high plasticity. If this clay material is to be considered for a landfill with a specific waste type (e.g. municipal solid waste, hazardous waste) compatibility of the clay with the waste should be explored further through additional chemical and mineralogical testing on the clay.

Sand and Gravel Aggregates

Aggregates are defined as hard, inert materials such as gravel, sand and crushed stone, that are used in the construction industry (Ricketts, 2002). In the Strait of Canso region there are several large aggregate quarries (e.g. Martin Marietta quarry at Cape Porcupine) using crushed granite and servicing Eastern US markets. Additional potential

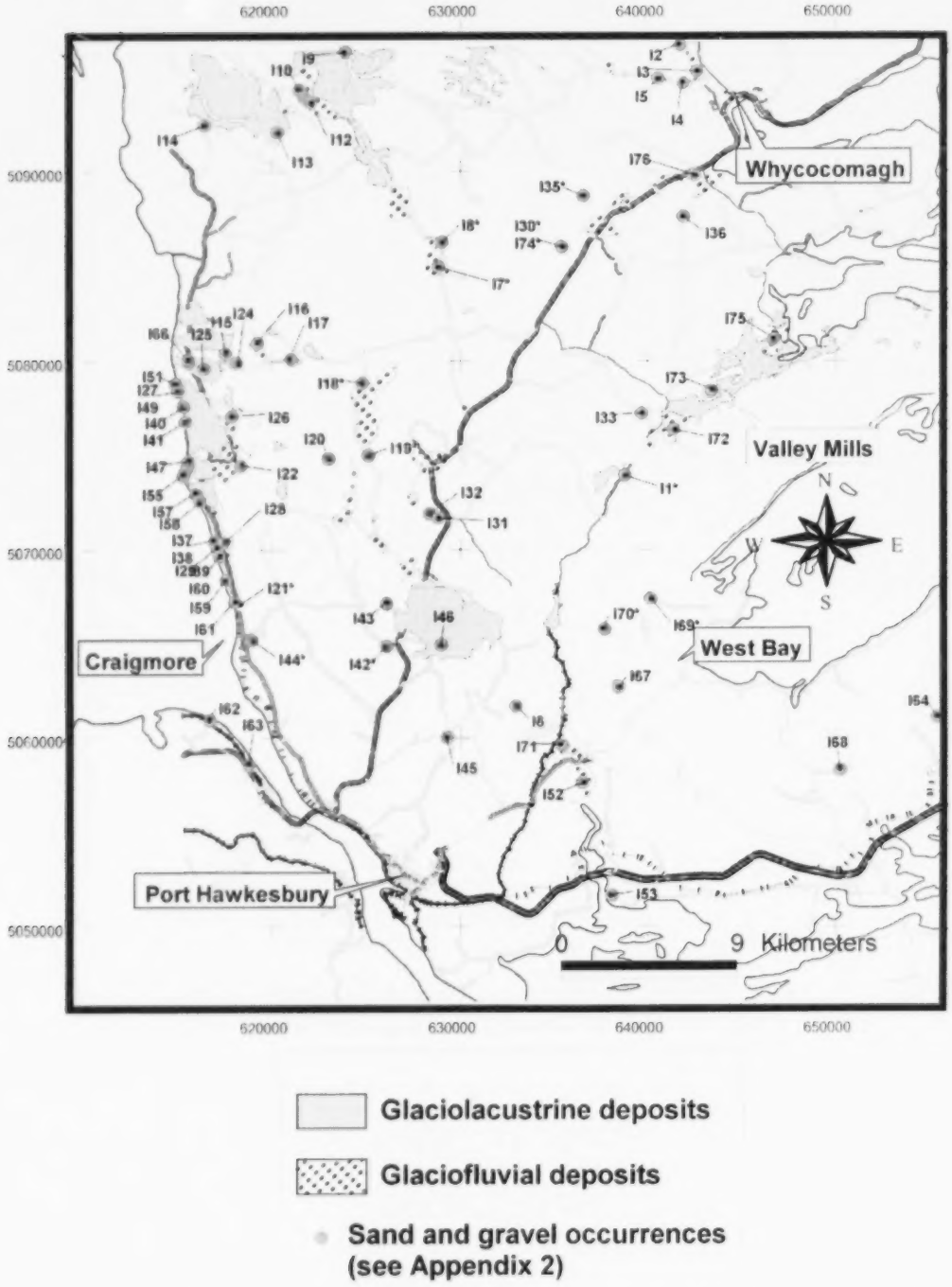

Figure 29. Location of sand and gravel occurrences in Inverness County (NTS map sheets 11F/14 and 11F/11; see Appendix 2 for occurrence data).

Table 6. Hydrogeological properties of clay samples from the Moran and River Denys basins.

	Sample 1 (55/00)	Sample 2 (48/04)
Moisture Content	29	25
% Sand	0	0
% Silt	45	46
% Clay	55	54
Plastic Limit	27	23
Liquid Limit	47	49
Plasticity Index	20	26
Hydraulic Conductivity	1×10^{-10} m/s	9×10^{-11} m/s

exists from weathered rock or residuum (Prime, 1992), which is currently being quarried on the east side of the Creignish Hills (Map 1).

This report focuses on aggregates from glacial materials. Glacial sand and gravel deposits are found throughout Inverness County and are used for a variety of purposes, such as fill for road and building construction. Potential uses include aggregate for concrete and asphalt manufacture. Sand deposits, by themselves, can have uses in landscaping, topsoil mixes, compost sands and water filtration. Some of the deposits described in this report are being mined without processing in semi-permanent pits termed "borrow pits" (Appendix 2). There are two major types of glacial deposits that produce coarse aggregates: glaciofluvial and glaciolacustrine deposits. Glaciofluvial deposits, such as kames and outwash, are the most suitable deposits for aggregate material. Generally these deposits are clean, low silt-clay, gravelly materials resulting from subaerial transport and deposition by glacial meltwater. Glaciolacustrine sand deposits, on the other hand, tend to be finer grained, less well sorted and sand dominated, deposited subaqueously in a glacial lake (Fig. 2).

The locations, grain size descriptions and deposit types in Inverness County, specifically in NTS map areas 11F/14 (Whycocomagh, Map 1) and 11F/11 (Port Hawkesbury; Map 2) are summarized in Figure 29 and Appendix 2. Kame deposits are perhaps the most important source of coarser-grained sand and gravel aggregates. These deposits, whose topographic expression and sedimentology were described earlier (Fig. 2), are variable in grain size and sorting. The aggregate quality of kame deposits can also be variable, largely depending on the nature of bedrock sources that were eroded by the glacier and glacial depositional processes. In general, older rock types such as granitic, volcanic and metamorphic rocks, found largely in the Creignish Hills and North Mountain, provide the best aggregate as these rock types are more resistant to abrasion and fracture under stress. One kame pit in the study area (I 69; Appendix 2; Fig. 26), north of West Bay on the flank of the North Mountain, was analyzed for aggregate properties in detail in an unpublished Nova Scotia Department of Mines and Energy report (Appendix 2) associated with a study by Fowler (1975). The sample comprised about 60 lb. of a representative channel sample through the deposit. The deposit is composed of 43.1% gravel, 56.9% sand and 1.1% fines, and is dominated by hard granite, volcanic and metasedimentary (quartzite) rock types (88.7%). A series of specific tests for aggregate quality were conducted on the deposit, including the Los Angeles Abrasion Test (LAAT), soundness and petrographic analysis. These tests were conducted to determine the competence and durability of the aggregate compared with other sources and are described in detail in Prime (1992). The LAAT is a measure of abrasion resistance carried out by rotating the materials in a drum and determining the weight loss. The soundness test is a measure of resistance to freeze/thaw and conducted by immersion in a sodium sulphate solution and drying. The chemical

reactions induce expansion and contraction emulating freeze/thaw. Weight loss during the immersion cycles is compared to known standards. Finally, in the petrographic analysis rock types are grouped according to their hardness and acid reactivity, and the percentages in each grouping are multiplied by a factor in each category (Excellent = 1, good = 3, fair = 6, poor = 10) to obtain a number between 100 and 1000. A petrographic number of no greater than 135 is required for asphalt concrete in Nova Scotia.

On the basis of these analyses the West Bay gravel pit (I 69; Fig. 26) provides materials suitable for all types of aggregate. Based on the geological setting of the West Bay site, and the source materials, we can postulate a number of other higher quality gravel sources, primarily in kame deposits on the margins of the highland blocks, dominated by harder, older rocks. These are marked with asterisks on Figure 29 and in Appendix 2.

Outwash deposits are also an important source of aggregate. As described earlier, these deposits are formed by meltwater streams in front of a retreating glacier. These deposits are largely found adjacent to or in the lowland areas. They generally have a higher percentage of softer, lowland rocks including Carboniferous sandstone, siltstone, limestone and gypsum. A detailed aggregate quality test (Appendix 2) was conducted on a sample collected near Long Point (I 22; Fig. 28; Appendix 2). The petrographic number of this deposit is 200, making it useful only as fill.

Glaciolacustrine deposits basins, such as those found in the Moran basin (I 10-Fig. 26) and Judique coastal plain (I 55; Fig. 28) also feature thick sand-dominated sections that may have potential for landscaping uses and as filtration sands.

Water Supplies from Surficial Aquifers in the Region

Sand and gravel deposits found throughout the study area may have the potential to supply potable water in an area where development of groundwater supplies has proven difficult in the past. Water-bearing units or aquifers within these glacial deposits can be divided into two types:

- unconfined aquifers in shallow ice contact deposits (kames/glaciofluvial gravel)
- confined or semi-confined aquifers in glaciofluvial and glaciolacustrine sand and gravel, buried under and/or between clay and till deposits.

Ice Contact Sand and Gravel

These aquifers are relatively common, especially on the flanks of highlands such as North Mountain and the Creignish Hills. Springs and seeps often occur where the hillside kame gravel deposits overlie bedrock or lower-permeability glacial till. Depending on the saturated thickness and the lateral extent of these gravels, water supplies may be developed, at least with sufficient yields to meet domestic demands. However, conflicting land-use demands, such as sand and gravel extraction and clear cutting, may render these potential aquifers useless.

Water supplies in surficial gravels that have been derived from the granitic and metamorphic rocks of the highlands generally yield good quality water, relatively soft and low in dissolved solids. Use of surficial maps (e.g. Grant, 1994; Stea and Feetham, 2003) can aid in the evaluation of areas with the potential for water supply development.

Buried Glaciofluvial/Glaciolacustrine Sand and Gravel

Based on the drilling carried out for this study, buried sand and gravel confined between clay and till deposits are extensive in the lowland basins (Fig. 1). These deposits have a better potential for the development of higher-yield water supplies. During the TGI drilling project, buried sand and gravel in the Big Marsh and River Inhabitants lowlands were found to be under flowing artesian conditions.

Drilling at KV-01-02 near Kingsville (Figs. 13, 14) encountered flowing artesian conditions at about 27 m in a 1-2 m thick gravel unit, which was overlain by clay and underlain by till. During the drilling process this section of the hole was cased off, terminating the groundwater overflow. No water sample was collected from this depth. Drilling continued to a depth of 88 m, where the

hole was terminated in grey shale (presumably Windsor Group sediments). As the drill rods were retrieved from the hole, groundwater started to overflow at a rate of 6.8 l/min. As reported in Appendix 5, calculations indicated this water was from the bottom of the hole, not the 27 m level where the first water was encountered. The water was sampled and found to be brackish and non-potable, probably because of a hydraulic connection with Windsor Group salt deposits at the basin margins (Boehner, 1986). The first water in the gravel unit at 27 m was likely fresh, as indicated by the conductivity log of KV-01-02 (Fig. 1) which shows a decrease in conductivities in the vicinity of the gravel.

The information obtained from this drillhole supports information encountered in other wells in the lowlands of the Bras d'Or Lakes watershed. With depth, water quality often deteriorates, especially in areas underlain by Windsor Group sediments. If the buried sand and gravel are separated from the bedrock surface by a relatively impermeable clay, or till deposits, then the aquifer may be protected from the influence of the poor water quality normally associated with the Windsor Group and/or fault systems. This may be the case within the Big Marsh lowlands (Figs. 17, 18) where a gravel aquifer is underlain by massive silty clay similar to the River Denys surface clay deposits with permeabilities in the order of 10^{-10} m/sec (Table 6).

Drilling at RDC-01-1 (Fig. 18) at the western or southern end of the Big Marsh lowland revealed artesian flow in a gravel unit at 13-18 m depth. The gravel unit was confined between the Sugar Camp and Richmond tills above and glaciolacustrine clay below. This aquifer was not tested, but a conductivity log of drillhole BM-01-1 in the Big Marsh lowland (Fig. 16) shows much lower pore water conductivities in the River Denys basin, which lacks the salt diapirs of the Kingsville area (Boehner, 1986). This gravel unit may be correlative across the Big Marsh lowland as a water-bearing unit within thick glaciolacustrine clay, as seen on the seismic profiles (Fig. 21). This buried surficial aquifer, therefore, may have some potential as a water producer for the area and should be tested further.

If these relatively deep sand and gravel units are hydraulically connected to sand and gravel deposits on the upland flanks, then good quality potable water may be found recharging these buried, confined sand and gravel deposits. As seen in the test holes, the water is commonly under artesian conditions. In other deep bedrock channels in the region the fine sand was saturated and under "quick" conditions, resulting in difficult construction problems.

Ideally, water supply wells in sand and gravel should be constructed as screened wells. Well development, therefore, may involve test drilling to collect split spoon samples at regular intervals for sieve analysis, prior to actual construction of the production well. Upon completion of a production well and one or more observation wells, a pump test will reveal if the aquifer is hydraulically connected to a fresh water source, Windsor Group sediments, or to the Bras d'Or Lakes.

Potable groundwater is a valued ecosystem component. The sand and gravel deposits should be evaluated with respect to their potential for potable water. Any geological test drilling should involve a hydrogeological component where water samples are collected when water is encountered, and flow rates are measured where possible. Great care should be taken to seal test holes where poor quality water is encountered under vertically upward groundwater gradients, in order that deeper aquifers do not contaminate the more shallow, fresher aquifers.

Conclusions

In this report we have outlined in some detail the geology and economic potential of glacial sediments in Inverness County, Cape Breton Island. It can be used as a template for further development of each resource, namely:

1. pottery, artware and slips,
2. structural products (brick and tile),
3. liner clays,
4. aggregates, road base, asphalt, landscaping sands, and
5. water supplies.

The summary (Page 2) provides the conclusions of this study. Appendix 6 is a further summary of recommendations to the Strait-Highlands Regional Development Agency for the evaluation of the clay

resources in the study area. This geological report is a first step in the process of economic evaluation of the clay resources, which would include market evaluations and further detailed testing within each of the basins, especially in the areas not evaluated by this study.

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Appendix 1

Ceramic Analyses and Interpretation from Mission Clay Products, Pittsburgh, Kansas

Includes:

1. Ceramic Report of Test Samples from Moran Basin (see Table 1).
2. Thermal Dilatometric Analysis (TDA) and Derivative Thermal Gravimetric Analysis (DTGA) Curves.
3. Chemical Analyses of Test Samples.

Ceramic Report of Test Samples from Moran Basin (see Table 1)

mission clay products

Division of MCP Industries, Inc. 10/1/90

P.O. Box 6 • Pittsburg, KS 66762 • (620) 231-1400 • Fax (620) 231-5663

March 20, 2003

R. J. Ryan, Ph.D.
Manager of Resources Evaluation
Geological Services Division
Nova Scotia Department of Natural Resources
P.O. Box 698
Halifax, Nova Scotia B3J 2T9

Dear Dr. Ryan:

January the 27th we received the four raw material samples from your Department of Natural Resources. We had previously received information that they were clays from an extensive red clay deposit found in Cape Breton, Nova Scotia, Canada and you desired comprehensive testing of their ceramic characteristics. The samples each contained documents with them designating them as Moran samples with individual numerical labels 31-02, 32-02, 34-02 and 55-00.

Testing Procedure

As received, the samples were in plastic bags inside of plastic pails. Observation indicated the material was indeed clay that was deep red in color similar to earthy hematite. Because the clays were wet, we placed them in large paper bags and dried them in our large sample dryer. Once they were dry, they were crushed and ground through our hammer mill where they attained the size recorded on the dry screen test results. From those ground samples, samples were obtained for the Carbon, Sulfur and Quartz determination, nine oxide analysis, dry screen, wet screen and particle size analysis by sedimentation. Further pulverizing and grinding were required to prepare samples for Carbon, Sulfur, Quartz and oxide analysis.

Eighteen pounds of initial ground sample was placed in our ribbon mixer for tempering prior to extrusion. The clay was tempered with water until the results of yield pressure testing indicated the sample was of the proper consistancy for extrusion. The tempered clay batch was then fed into the extruder until the extrusion auger was full of clay. Once it was full of enough clay for a seal, the vacuum pump was turned on and vacuum was obtained

in the transfer vacuum chamber between the feed and extrusion augers. Extrudate was extruded until it was well deaired, then samples were taken for testing. The vacuum was retained at +/- 27 inches of mercury during extrusion. Initially several short one-inch diameter test bar samples were obtained for fast drying testing, slaking and plastic index determination on our Instron. Then eleven test bars were extruded 11½" long. One of the eleven was weighed and dried for extrusion moisture content calculation then fired to determine the ignition loss of the remaining ten. Two are dried and broken to determine their dry modulus of rupture(MOR) of the remaining eight bars after drying, six are fired in our large gas fired kiln. Once all the MOR, etc., samples are extruded, a die change is made during which penetrometer reading and shear testing is conducted on the extrudate clay in the extension going to the die. A small diameter die is installed and three 11" long bars are extruded to be used, after they are dried, for sag testing in the kiln during firing of the MOR test bars. One more die change is made. Then the three largest diameter bars are extruded; they are 46mm in diameter by 4½" long. These large diameter bars are used to be inspected for their internal unoxidized black iron core and/or lamination tendency after firing, once they are sawn into two parts. Those sample pieces are large enough that most clays will have a core within them after firing.

Once all the test bars are extruded, labeled and marked for shrinkage, they are placed into a drying rack for 24 to 48 hours. Then they are placed in our intermediate dryer where they are fanned with warm air. Finally they are placed into a static dryer and heated to 225°F. for at least 16 hours until they are a constant weight. The bars to be beam broken and used for the dry MOR determination are transferred to a desiccator and cooled to ambient temperature before they are broken. We normally obtain two breaks per test bar. The test bars to be fired are taken directly to the kiln from the dryer, while they are still hot and set into the kiln on kiln furniture up off the deck for firing. The sag bar is suspended between 7½" centers during firing.

The samples are fired in a large under deck gas fired kiln fitted with three burner tips on two of the sides. The firing schedule used is approximately seven to eight hours in length depending on the top firing temperature. The burner flame is set to obtain a oxidizing atmosphere throughout the firing cycle. There is a 2 hour 15 minute oxidation soak at 1650°F. that begins after approximately three hours into the firing cycle. With the typical schedule the kiln is held at the top firing temperature for approximately 45 minutes before the kiln burners are turned off and cooling begins.

Because of the short firing cycle it is necessary to fire to a top temperature some 25°-30°F. higher than is required in the typical production kiln to obtain comparable firing characteristics. Five to nine Bell Research fire chek keys are set with the samples prior to firing and are measured after firing, as a measure of the time - temperature heat work done during firing. Key cheks are also pulled from a small rack inside the kiln during the top temperature soak. After three to four minutes of cooling at room temperature, the removed key cheks are measured and their readings recorded so that firing can be precisely duplicated in the future or as a previous firing schedule is being matched.

After the firing is completed, the kiln is allowed to cool naturally until the following morning when the top of the setting door is removed and the kiln allowed to cool to just below 300°F. The door is then removed and the samples are dwawn from the kiln while they are still hot. Three of the fired bars from each series are promptly placed in a desiccator for cooling to room temperature prior to being beam broken for the initial MOR calculation. The breaks are on 5" center spans resulting in two breaks per bar. The second group of three test bars are cooled to near room temperature, placed in a pressure cooker, flooded with water and boiled for one hour. The samples in the pressure cooker are then cooled while still submerged in water to room temperature. The bars are then removed and immediately broken to determine their aged MOR after having been subjected to this accelerated ageing test.

Discussion of Test Results

When you observe the oxide analysis of the four samples, you will notice the relatively low percentage of Aluminum oxide. The percentages of Aluminum indicate the clay is not Kaolinite. The relatively high percentage of Iron oxide give the samples their color The relatively high percentage of Potassium oxide will act as a powerful flux during the firing of the samples lowering their vitrification temperature and is indicative of the clay mineral Illite.

Observation of the thermal test curves - Thermal Dilatometric Analysis (TDA) and Derivative Thermal Gravimetric Analysis (DTGA) show when and how the clay expands, contracts and loses weight during firing. The DTGA curves of the clays compliment the chemical analysis of those samples, show the magnitude of the free water loss after the samples have been dried to 225°F., the magnitude and range of organic Carbon burnout, the evolution of the

crystal water from the clay minerals and the evolution of Carbon Dioxide from Dolomite combined with the clay. The configuration of the DTGA curves are consistent with those we have come to expect from samples that contain a predominance of the clay mineral Illite. That conclusion of the presence of Illite is complimented by the configuration of the TDA curves, the oxide analysis and the relatively low percentages of Quartz. The location of the beginning of vitrification are very low for a common commercial clay. The low vitrification temperatures are the result of the small particle size, alkali and iron content of the samples. The lack of marked offsets at the Alpha to Beta Quartz inversion location on the TDA curves verify the low Quartz contents of the samples.

The chemical analysis of the samples show they contain low percentages of organic Carbon. The inorganic Carbon content is higher than would be found in a typical clay. Apparently the dolomite or limestone from which most inorganic Carbon is derived is finely divided and combined with the clay because we saw only moderate effervescence when the wet screen retains were tested with dilute hydrochloric acid. Also no lime "pops" have developed on the fired samples. There was no Sulfur detected when the samples were analyzed by the combustion technique to 2100°F. The analysis of the samples for their Quartz content show it to be very low. The low Quartz content should relate to relatively safe cooling of commercial products made from this material due to low contraction from Beta back to Alpha Quartz during that inversion during the cooling cycle.

The three larger samples (32-02, 34-02 & 55-00) all have good plasticity because of their high percentage of particles less than 2 microns and their lack of natural stone (plus 200 mesh material retained after wet screening). Their tendency to laminate is severe because of the same reason they are so plastic - fine particle size with a lack of natural stone. The good news is that despite their fine particles, relatively high demand for water of extrusion and high drying shrinkage, they dry very good. The dry strengths are good, though not exceptional, because of the laminations in the interior of the dry samples. After reviewing the TDA curves and the thermal shrinkage percentages, the decision to fire the samples to 1840°F. with a 45 minute top temperature soak was made. This top temperature, which we used for our aggressive kiln schedule rate, would be approximately 25-30°F. hotter than would be required in a commercial kiln. That top firing temperature is extremely low for firing any clay that would develop this high of a fired shrinkage, low of a boiled water absorption and such excellent strengths.

The fired strengths would no doubt be higher if it were not for the laminations in their bodies. We suspect those laminations also contributed somewhat to elevate the boiled water absorption percentages. We believe the laminations also contributed to the high strength loss during the accelerated ageing test of the sample 34-02. Even with the strength lost thru ageing the final aged strengths all are excellent.

The weight lost during firing is in the range one would expect with an Illitic type material. The sag of the test bar suspended only at each end is low for this type material that developed boiled water absorption results in the range these samples developed.

Even though the organic Carbon levels are very low, there were unoxidized black iron cores within the center of the large diameter core bars after firing. We believe the primary reason the black cores were not oxidized during firing is the tight nature of the extrudate body because of the high percentage of clay and silt size particles and the lack of any significant natural stone in the samples. The tightness of the body impedes the penetration of oxygen during firing to oxidize the reduced black iron and convert (oxidize) it to red iron. The oxidation (clearing) of the core normally takes place during the oxidation soak and then only after the CO^2 from the dolomitic limestone has all been expelled.

No oxygen can go into the body while CO_2 is coming out. That CO_2 can be a significant factor in the ability of a body to be oxidized during firing.

The results of the particle sizing obtained when we ground the clays in preparation for extrusion are seen in the results of the dry screen testing. The particle distribution is similar to that which is used for brick manufacturers. The wet screening test results from the four samples is remarkable. We do not recall having seen common clay of the Illite variety with less natural stone or more silt and clay. There is more than 50% of these materials that are less than 4 microns. The 31-02 sample is the coarsest of the group only because it contains 10-15% more coarse silt size material.

Conclusion

The four samples from Cape Breton labeled Moran have ceramic characteristics of an extremely weathered Illitic shale. They could be classified as common clay. The clay is unusual because of its' large percentage of coloidial particle size, low vitrification temperature and very good fired strength. Because of its'

demand for a higher than normal percentage of extrusion water, lamination tendency during extrusion and high dry shrinkage; we doubt the clay could be safely used for the manufacture of structural clay products by itself. If one of the materials could it would be the 31-02 sample.

Because the clay has the characteristics listed above it should have the ability to be used to make structural clay products provided it is blended with the proper non-plastic additive that would significantly increase its' natural stone content (plus 200 mesh up to 10 mesh size). The addition of such a non-plastic would reduce its' demand for water for extrusion, reduce or eliminate the tendency to laminate, reduce the dry shrinkage and increase the vitrification temperature. The proper firing temperature should be higher if the product made would require relatively low boiled water absorptions.

The proper non-plastic could be igneous rock fines -- such as granite, light weight aggregate, various grogs, hard non-plastic shale, slate, sandy shale, sand, etc.

Products that could be made from this clay and non-plastic blend could be face brick, flower pots, tile, flue lining, drain tile, paving brick and sewer pipe.

One of the best virtues of this clay is its' relatively low firing temperature which could result in less energy needed to fire the products as oppossed to typical clay and shale products requiring higher temperature firing.

Sincerely,

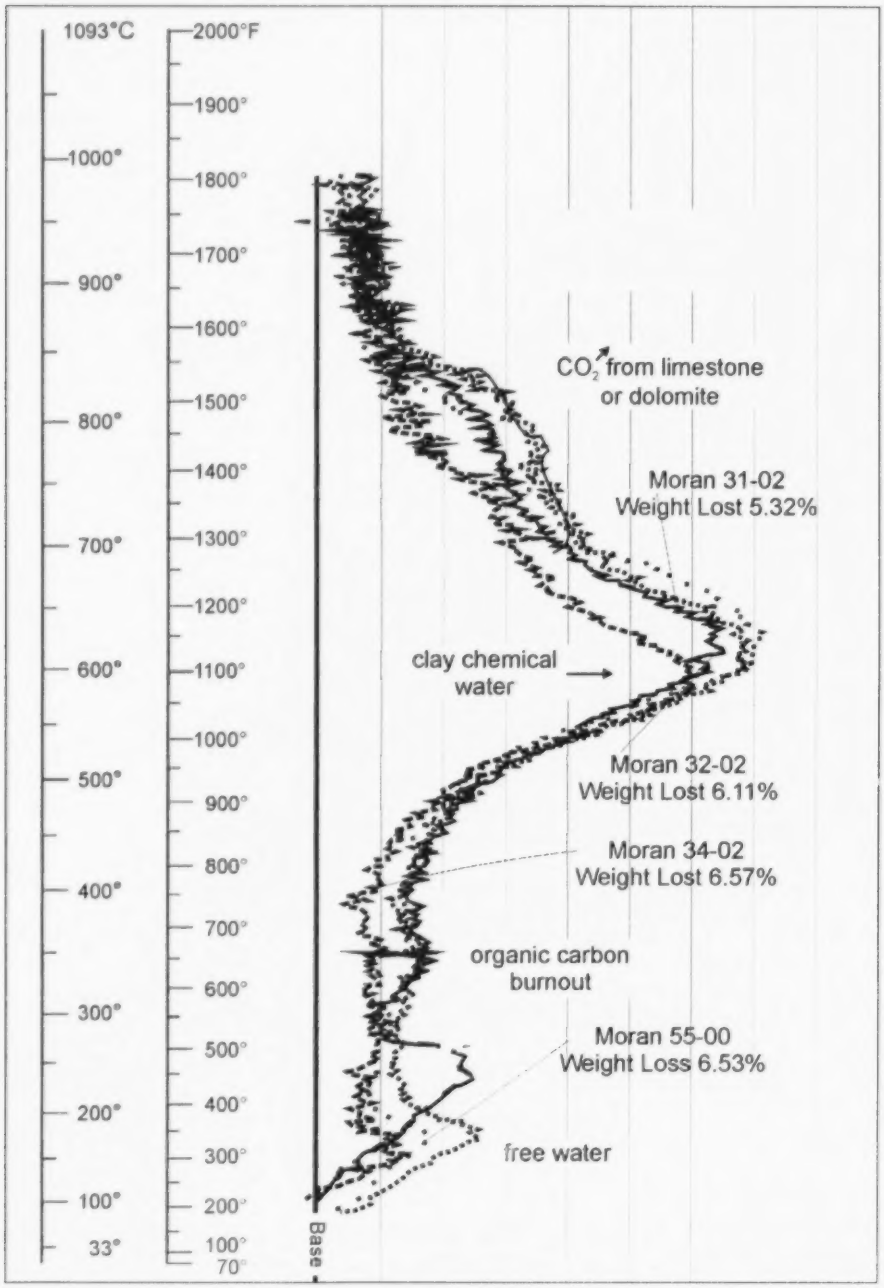
A. Joel Frazier

A. Joel Frazier
Manager Ceramic Technology
Chief Geologist

AJF/df
Enclosure

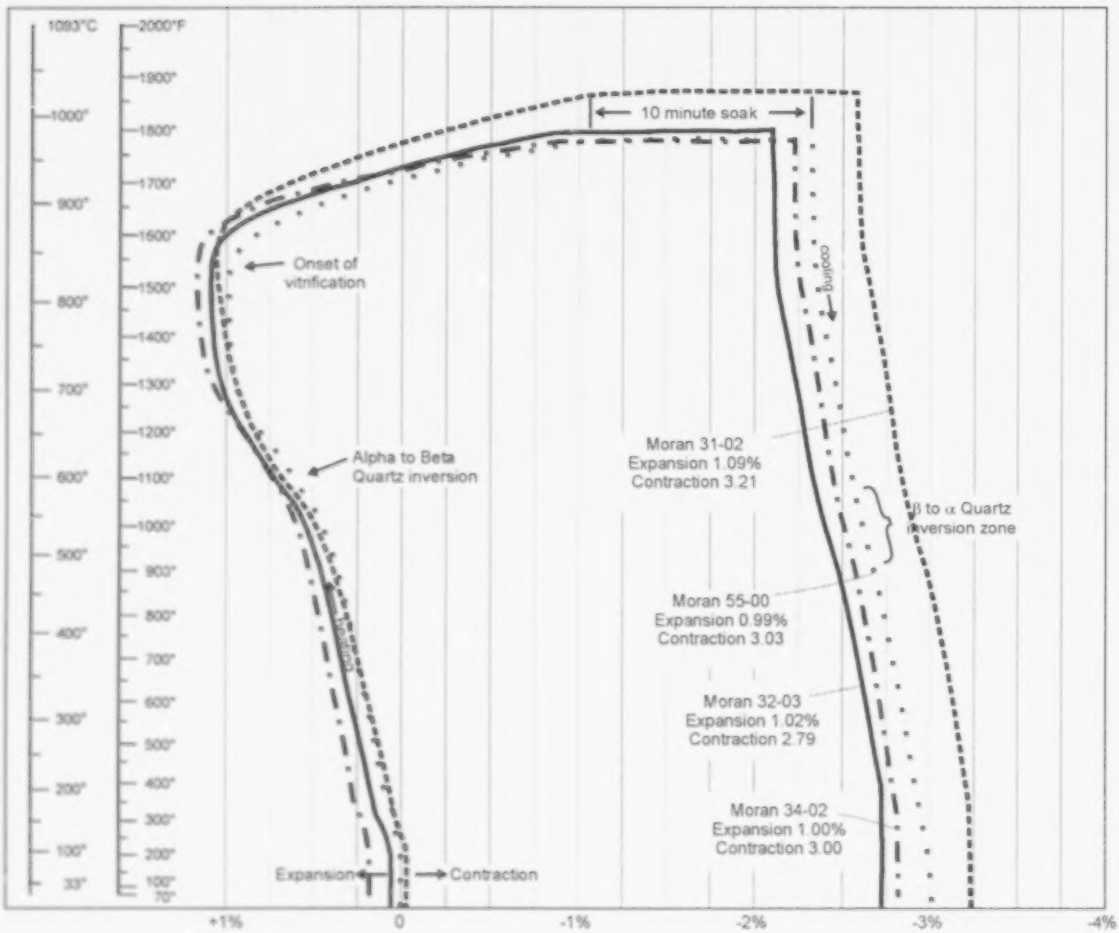
Thermal Dilatometric Analysis (TDA) and Derivative Thermal Gravimetric Analysis (DTGA) Curves

Derivative Thermal Gravimetric Curves (DTGA) Moran clay



Rate of Weight Loss

Thermal gravimetric curves (TDA) Moran clays



Chemical Analysis of Test Samples

MISSION

Please find listed below analysis on the following clay sample.

Lab ID. SF10-2 Sample ID. 55/00 Moran.

Clay Oxide Analysis

Silicon Dioxide	48.22%
Aluminum Oxide	15.32%
Ferric Oxide	7.58%
Calcium Oxide	0.10%
Magnesium Oxide	1.71%
Sodium Oxide	0.81%
Potassium Oxide	5.18%
Titanium Dioxide	3.00%
Manganese Dioxide	0.04%
Loss on ignition at 1750 F	6.09%
Moisture at 105 C	1.06%
Undetermined	10.89%

*Less than detection limit

Respectfully,

Carrol Luman

MISSION

Please find listed below analysis on the following clay sample.

Lab ID. SF10-3 Sample ID. 34/02 Moran.

Clay Oxide Analysis

Silicon Dioxide	47.26%
Aluminum Oxide	15.45%
Ferric Oxide	8.01%
Calcium Oxide	0.08%
Magnesium Oxide	1.70%
Sodium Oxide	0.76%
Potassium Oxide	5.35%
Titanium Dioxide	2.78%
Manganese Dioxide	0.04%
Loss on ignition at 1750 F	6.07%
Moisture at 105 C	1.20%
Undetermined	11.30%

*Less than detection limit

Respectfully,

Carrol Luman

MISSION

Please find listed below analysis on the following clay sample.

Lab ID. SF10-4 Sample ID. 31/02 Moran.

Clay Oxide Analysis

Silicon Dioxide	50.00%
Aluminum Oxide	16.36%
Ferric Oxide	7.52%
Calcium Oxide	0.04%
Magnesium Oxide	1.28%
Sodium Oxide	0.84%
Potassium Oxide	4.94%
Titanium Dioxide	3.00%
Manganese Dioxide	0.04%
Loss on ignition at 1750 F	5.22%
Moisture at 105 C	0.93%
Undetermined	9.84%

*Less than detection limit

Respectfully,

Carrol Luman

MISSION C P

Please find listed below analysis on the following clay sample.

Lab ID. SF10-5 Sample ID. 32/02 Moran.

Clay Oxide Analysis

Silicon Dioxide	49.76%
Aluminum Oxide	14.19%
Ferric Oxide	7.01%
Calcium Oxide	0.09%
Magnesium Oxide	1.40%
Sodium Oxide	0.92%
Potassium Oxide	4.75%
Titanium Dioxide	3.28%
Manganese Dioxide	0.06%
Loss on ignition at 1750 F	5.40%
Moisture at 105 C	0.99%
Undetermined	12.15%

*Less than detection limit

Respectfully,

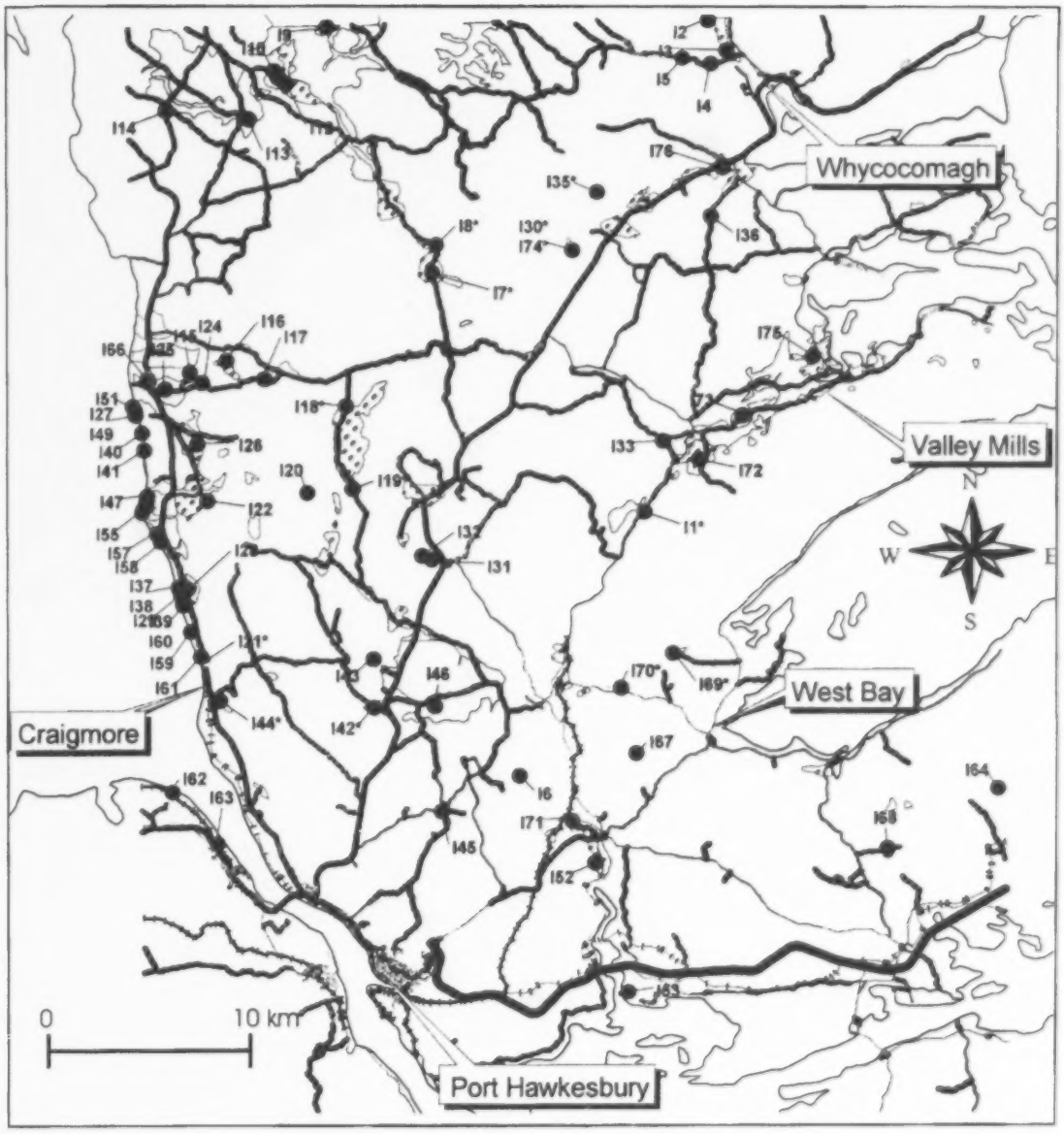
Carrol Luman

Appendix 2

Sand and Gravel Occurrences in Inverness County

Includes:

1. Map of occurrences.
2. Table of site data.
3. Aggregate testing results from Long Point (Site I22) and Campbell Brook (West Bay site I69).



Glaciolacustrine deposits

Glaciofluvial deposits

• Sand and gravel occurences (see Table 1)

SITE	NORTHING	EASTING	STRATLOG	DEPOSIT TYPE	LOCATION
RS 1/00	5073158	639447	Gravelly-sand >20m on side of hill overlooking River Denys	Kame terrace- borrow-pit- granite- red ss	I1
RS 15/00	5095334	642241	Gravelly sand deposits, mostly medium to fine sand	Kame terrace- borrow pit	I2
RS 16/00	5093988	643092	Bouldery-gravel and medium to fine sand, poorly sorted	Kame - road cut	I3
RS 18/00	5093375	642406	Bouldery gravelly sand and sand, road cut, <25m thick	Kames	I4
RS 19/00	5093631	641111	Gravelly sand exposure in kames	Kames-borrow pit	I5
RS 21/00	5061230	633804	Veneer of medium to coarse sand over red brown silty till <2m	Road cut	I6
RS 35/00	5083934	629847	Bouldery gravelly sand-sand	Kame ? Borrow pit- diorite basalt granite slate	I7
RS 36/00	5085199	630013	Massive coarse to medium sand poorly sorted	Kames-road cut	I8
RS 42/00	5094999	625067	Pebbly, gravelly-sand, massive, crude horizontal strat. 2-5m	Outwash -borrow pit- clay underneath	I9
RS 51/00	5093034	622723	Pebbly gravelly-sand 15m overlying silty clay, gyp.	Outwash river exposure	I10
RS 52/00	5092678	622972	Openwork gravel/ bouldery gravelly-sand	Proximal outwash? gravel pit cong., granite, siltst., gabbro	I11

SITE	NORTHING	EASTING	STRATLOG	DEPOSIT TYPE	LOCATION
RS 53/00	5092448	623276	Cross-bedded coarse-medium sand-gravel	Distal outwash- gravel pit	I12
RS 60/00	5090870	621603	Gravel veneer over till	TERRACE-river cut	I13
RS 74/00	5091227	617868	Laminated medium to coarse silty sand over till	Glaciolacustrine - road cut	I14
RS 94/00	5079459	618962	Gravelly-sand	Borrow pit	I15
RS 97/00	5079998	620591	Gravelly-sand-cobbles-boulders	Outwash proximal- delta-borrow pit. Diorite ss.	I16
RS 98/00	5079149	622297	Bouldery gravel-sand overlying m-c sand	Outwash delta-borrow pit-diorite-granite, ss	I17
RS 99/00	5077938	625955	Bouldery-gravelly-sand-mounds	Kame moraine?- borrow-pit	I18
RS 101/00	5074194	626262	Stony, sandy diamicton angular and rounded clasts	Kame moraine, road cut-diorite-granite	I19
RS 104/00	5074010	624239	Gravelly-sand, bouldery, mounds.	Kames-road-cut	I20
RS 114/00	5066520	619744	Gravelly sand (20m) folded beds at core of kame	Kame- gravel pit-granites	I21
RS 115/00	5073661	619744	Gravelly sand, channels	Kames-outwash over?-borrow pit	I22
RS 01/01	5092678	622962	BGS/m-cS/G	Proximal outwash-BORROW PIT- white granites, congl.,	I23
RS 25/01	5078989	619508	Gravelly-sand over thin peat layer	Kames ROAD CUT GRAVEL VENEER	I24
RS 26/01	5078699	617838	Sandy-silt/ gravelly sand	Kames- ROAD CUT	I25

SITE	NORTHING	EASTING	STRATLOG	DEPOSIT TYPE	LOCATION
RS 27/01	5076223	619295	GS fine- few cobbles->15M	Glaciofluvial BORROW PIT-delta?	I26
RS 28/01	5077665	616494	mF/m-cS/peats/ si/ Dmm 4 m	Glaciolacustrine SEA CLIFF: Younger dryas	I27
RS 31/01	5069685	618865	BGS->7m	Kames BORROW PIT	I28
RS 32/01	5069392	618538	m-fS/F/m-fS--5m	Glaciolacustrine SEA CLIFF	I29
RS 194/01	5084954	636175	BGS	Kames terraces	I30
RS 168/00	5071004	629828	mF2m/peat	Glaciolacustrine stream cut	I31
RS 169/00	5071188	629398	GS 2m	Glaciolacustrine stream cut	I32
RS 171/00	5076375	640281	MF/GS	Alluvial Stream flood plain (photos)	I33
RS 177/00	5087585	637277	BGS-2m/Dm st-sd	Kame road cut	I35
RS 178/00	5086498	642418	BGS-2m/S-GS	Outwash borrow pit-channelized	I36
RS 33/01	5069756	618430	m-fS/GS/Dmm 15m	Glaciolacustrine sea cliff	I37
RS 34/01	5069767	618431	BGS/GS/m- IF/GS/ F 8m	Glaciolacustrine sea cliff	I38
RS 35/01	5069024	618624	BG/Dmm >20m	Glaciolacustrine sea cliff	I39
RS 38/01	5076719	616797	mS- 3m/peat1m/ Dmm 9m	Glaciolacustrine sea cliff	I40
RS 41/01	5075953	616893	mF/si/S/Dmm-20m	Glaciolacustrine sea cliff	I41
RS 56/01	5064327	627202	BGS	Outwash delta? borrow pit	I42
RS 57/01	5066511	627186	cS/s	Outwash delta borrow pit	I43
RS 59/01	5064657	620299	BGS	Kame borrow pit	I44
RS 63/01	5059616	630281	BGS/IF/BGS/ Dmm-6m	Glaciolacustrine stream cut	I45
RS 66/01	5064404	629977	GS-1m	Glaciolacustrine road cut	I46
RS 69/01	5073879	617037	F.5m/xbS3m/mF-S 3m	Glaciolacustrine sea cliff	I47

SITE	NORTHING	EASTING	STRATLOG	DEPOSIT TYPE	LOCATION
RS 70/01	5073685	617022	BGS-2m/m-cS 6m	Glaciolacustrine sea cliff	I48
RS 71/01	5077509	616514	mF/fS/peat/Dmm 3m	Glaciolacustrine sea cliff	I49
RS 72/01	5077767	616448	mS/Dmm-5m	Glaciolacustrine sea cliff	I50
RS 73/01	5077906	616380	IS/BGS/Dmm clay 4m	Glaciolacustrine sea cliff	I51
RS 78/01	5057304	637222	m-cS/GS	Kame borrow pit	I52
RS 86/01	5052006	638844	BGS/Dmm	Kame? road cut	I53
RS 97/01	5073510	616966	BGS/S/xbS/S	Glaciolacustrine sea cliff	I54
RS 98/01	5073252	616848	fS/grS/	Glaciolacustrine sea cliff	I55
RS 99/01	5073126	616799	gS/Dmm 5m	Glaciolacustrine sea cliff	I56
RS 102/01	5072177	617456	mgS/mF/Dmm 20 m	Glaciolacustrine sea cliff	I57
RS 103/01	5071848	617632	BG/Dmm 6m	Glaciolacustrine sea cliff	I58
RS 105/01	5067755	618984	BGS 2-3m/?	Glaciolacustrine sea cliff	I59
RS 108/01	5068935	618648	BGS-3m/Dmm silty/	Glaciolacustrine sea cliff	I60
RS 112/01	5066[illegible]	619437	BGS 3.5m/Dmm silty-7m/GS-1m/ BR	Glaciolacustrine sea cliff	I61
RS 125/01	5060496	618145	BGS Cv/BR bench	Glaciolacustrine sea cliff	I62
RS 129/01	5058173	620186	BGS 2m/Dmc 5m	Glaciolacustrine sea cliff	I63
RS 140/01	5060650	655432	BG-S/BR gr.	Kame? road cut	I64
RS 155/01	5079017	617088	S/FDmm 3m	Kame road cut	I65
RS 156/01	5079160	617059	GS1m/m-cS2m	Kame ?road cut	I66
RS 185/01	5062240	639075	GS	Kame road cut	I67
RS 186/01	5057927	650427	G-S >4m	Alluvial road cut- Flood plain	I68
RS 187/01	5066782	640724	GS>5m	Kames borrow pit-	I69

SITE	NORTHING	EASTING	STRATLOG	DEPOSIT TYPE	LOCATION
RS 188/01	5065212	638377	GS-kame	Kame borrow pit	I70
RS 189/01	5059201	636184	BGS/Sg/GS	Kame borrow pit	I71
RS 193/01	5075541	641908	m-cSx/BGS/m- cS/ F/S forstes	Outwash borrow pit- delta	I72
RS 194/01	5077520	643862	m-cS 3m	Kame road cut	I73
RS 195/01	5084954	636175	GS->20m	Kame borrow pit	I74
RS 196/01	5080166	647013	BGS/S/mF1	Esker? borrow pit	I75
RS 197/01	5088668	642958	BGM-Dmm/GS/	Outwash borrow pit-	I76

Notes:

SITE: Stop location in the field as depicted on the geology maps (Maps 1 and 2) and in the surficial databases.

STRATLOG: abbreviations: (BGS) = bouldery gravelly-sand, m-fSx/F = (m-f) medium to fine-grained (S) sand, (x) crossbedded overlying (F)-silt and clay; Dmm = matrix-supported diamicton (See Eyles *et al.*, 1983 for further descriptions of facies code)

NORTHING/EASTING: Projection - Universal Transverse Mercator NAD 27.

CS-74-45 11 F/14

WARNOCK HERSEY INTERNATIONAL LIMITED • PROFESSIONAL SERVICES DIVISION
4 MACDONALD AVE., DARTMOUTH, N. S., TEL. (902) 463-8130

(Cathead Pit)

HIGHWAY AGGREGATE MATERIAL QUALITY CONTROL REPORT

For: Dept of Mines, Prov. of Nova Scotia, Granville St. Halifax, NS Att: Mr. John Fowler

Contract No. PRIVATE Laboratory No. 1523 Date March 23, 1976

Description of Sample: (1) Sample of Gravel Pit Run 2", Approx. 90 lbs.

Type of Mix: Hot Mixed Asphalt

Source: Clients sample No. 2 Long Point, Insurance Co.

Sampler: via Mr Gordon Dickie Date Sampled rec'd in lab on March 2, 1976

Contractor: -

DATA: 1. Grading Analysis

Percent Held on # 4 Mesh _____ Percent Passing # 4 Mesh _____

2. Los Angeles Abrasion Test

Grading B Percent Loss: after 100 revs ..... after 500 revs. 22.6

3. Soundness (5 cycles of Sodium Sulfate)

Total Weighted Loss of Coarse Aggregate, Percent 6.5

4. Petrographic Analysis (Modified D. H. O. Method)

Proportional Petrographic Number 204.1

5. Particle Description

Shape Sub Angular Percent Crushed Particles Not Counted

SUITABILITY: ☐ Meets Department Specifications for abrasion and soundness only.

☒ Fails to meet Specifications because:

Petrographic number exceeds 200.

REMARKS: Samples prepared by crushing to 3/4" Aggregate in laboratory.

Items Nos. 3 & 4, See detailed analysis attached

K.R. Hosier, C.E.T., Supervisor
LABORATORY SUPERVISOR

Long Point

MANNOCK MOSLEY INTERNATIONAL LIMITED
PROFESSIONAL SERVICES DIVISION

CONTRACTOR Client: Dept. of Mines, Prov. of Nova Scotia DATE March 22, 1976

CONTRACT NUMBER PRIVATE

NAME OF PIT Clients sample no. 2

SOUNDNESS TEST FIVE CYCLE SODIUM SULPHATE
ASTM DESIGNATION C-88-63

SAMPLE NO. 1523	DESCRIPTION OF MATERIAL 3/4" Aggregate crushed in laboratory.		
Sieve Size Held on	% Loss Each Frac.	DOH, NS "Ideal" ~~Original~~ Grading Percent	Percent Loss Weighted On Original Grading
COARSE AGGREGATE			
1"			
3/4"	(6.6)	5.0	0.3
1/2"		28.0	
3/8"	6.6	27.0	3.6
NO. 4	6.6	40.0	2.6
TOTALS	13.2	100.0	6.5

Note: DOH, N.S. specification for Asphalt Aggregate - 10% Maximum

Warnock Hersey Professional Services Ltd.

PETROGRAPHIC ANALYSIS

CONTRACT NO. PRIVATE LABORATORY NO. 1523 DATE March 23, 1976

DESCRIPTION OF SAMPLE LAB Crushed 3/4"-3/8" Fraction MIX TYPE B

SOURCE Clients sample #2

CONTRACTOR Client-Dept. of Mines, NS. DATE SAMPLED rec.d March 2, 1976

ROCK TYPES	QUALITY (PERCENT)			
	EXCELLENT (1)	GOOD (3)	FAIR (6)	POOR (10)
QUARTZITE	13.5			
GRANITE	13.2			
VOLCANIC	44.8	9.1	6.3	
SANDSTONE		4.1	8.7	0.3
TOTALS	71.5	13.2	15.0	0.3

PETROGRAPHIC NUMBER FOR HOT MIX 204.1

( ) FACTOR

CS - 74 - 123

WARNOCK HERSEY INTERNATIONAL LIMITED • PROFESSIONAL SERVICES DIVISION
4 MACDONALD AVE., DARTMOUTH, N. S., TEL. (902) 463-6130

514-0000

HIGHWAY AGGREGATE MATERIAL QUALITY CONTROL REPORT

for Dept. of Mines, Province of Nova Scotia, Granville St., Halifax, N.S. Attn: Mr. Gordon Dickie

Contract No. PRIVATE **Laboratory No.** 1543 **Date** May 21, 1976

Description of Sample: (1) bucket of Pit Run (5" Max.) Approx. 60 lbs.

Type of Mix: H.M.A. Type B

Source: Clients Sample Mark: Campbell Brook #1 Inverness Co.

Sampler: received via Mr. G. Dickie **Date ~~Sampled~~** April 30, 1976

Contractor:

DATA: 1. **Grading Analysis** on Laboratory Crushed Sample

Percent Held on # 4 Mesh 43.1 Percent Passing # 4 Mesh 56.9

2. **Los Angeles Abrasion Test**

Grading B Percent Loss: after 100 revs. after 500 revs. 23.4

3. **Soundness (5 cycles of Sodium Sulfate)**

Total Weighted Loss of Coarse Aggregate, Percent 4.9

4. **Petrographic Analysis (Modified D. H. O. Method)**

Proportional Petrographic Number 135.2

5. **Particle Description**

Shape Percent Crushed Particles

SUITABILITY: ☒ Meets Department Specifications for abrasion, soundness and Petrographic number.
☐ Fails to meet Specifications because:

REMARKS:
Sample prepared by crushing in lab jaw to 3/4" max.
Item nos. 3 & 4. - Detailed analyses are given on sheets attached.

The above analysis was
put on the Computer List
as was other sieve analysis
mailed

K.D. Moulton, Geol. P.Eng. Supervising Engineer

Encl.

CS - 74 - 123

WARNOCK HERSEY INTERNATIONAL LIMITED • PROFESSIONAL SERVICES DIVISION
4 MACDONALD AVE., DARTMOUTH, N. S., TEL. (902) 465-8130

514-0000

HIGHWAY AGGREGATE MATERIAL QUALITY CONTROL REPORT

for Dept. of Mines, Province of Nova Scotia, Granville St., Halifax, N.S. Attn: Mr. Gordon Dickie

Contract No. PRIVATE **Laboratory No.** 1543 **Date** May 21, 1976

Description of Sample: (1) bucket of Pit Run (5" Max.) Approx. 60 lbs.

Type of Mix: H.M.A. Type B

Source: Clients Sample Mark: Campbell Brook #1 Inverness Co.

Sampler: received via Mr. G. Dickie **Date Sampled** April 30, 1976

Contractor:

DATA: 1. Grading Analysis on Laboratory Crushed Sample

Percent Held on # 4 Mesh 43.1 Percent Passing # 4 Mesh 56.9

2. Los Angeles Abrasion Test

Grading B Percent Loss: after 100 revs. after 500 revs. 23.4

3. Soundness (5 cycles of Sodium Sulfate)

Total Weighted Loss of Coarse Aggregate, Percent 4.9

4. Petrographic Analysis (Modified D. H. O. Method)

Proportional Petrographic Number 135.2

5. Particle Description

Shape _____ Percent Crshed Particles _____

SUITABILITY: ☒ Meets Department Specifications for abrasion, soudness and Petrographic number.
☐ Fails to meet Specifications because:

REMARKS:

Sample prepared by crushing in lab jaw to 3/4" nz.
Item nos. 3 & 4. - Detailed analyses are given o sheets attached.

This sieve analysis was put on the Computer List & not other sieve analysis needed

R.B. Nunn, Quality Control Supervisor
Laboratory Operations

FORM 183-M-60-E

WARNOCK HERSEY INTERNATIONAL LIMITED • PROFESSIONAL SERVICES DIVISION

File # 514-0000

AGGREGATE GRADATION TEST DATA

CLIENT: Department of Mines, Province of Nova Scotia
Granville St., Halifax, Nova Scotia
Attention: Mr. Gordon Dickie

CONTRACTOR:

SUPPLIER:

REPORT NO: 1543
DATE: May 21, 1976
DESCRIPTION OF MATERIAL: Pit Run (5")
SOURCE OF MATERIAL: Clients sample Mark: Campbells Brook #1 Rec'd via Mr. G. Dickie, on April 30, 1976

SIEVE ANALYSIS of sample after Lab Crushing to 3/4" max.

SAMPLE NO.	Whole Sample			Sand Fraction			SPECIFICATION REQUIREMENTS – PERCENTS PASSING SIEVE
SIEVE SIZE	FRACTIONAL PERCENT RETAINED	CUMULATIVE PERCENT RETAINED	CUMULATIVE PERCENT PASSING	FRACTIONAL PERCENT RETAINED	CUMULATIVE PERCENT RETAINED	CUMULATIVE PERCENT PASSING	
3"							
2"							
1½"							
1"			100.0				
¾"	2.7	2.7	97.3				
½"	14.5	17.2	82.8				
⅜"	11.3	28.5	71.5				
No. 4	14.6	43.1	56.9			100	
8	11.6	54.7	45.3	20.4	20.4	79.6	
16	16.3	71.0	29.0	28.6	49.0	51.0	
30	16.9	87.9	12.1	29.7	78.7	21.3	
50	7.9	95.8	4.2	13.9	92.6	7.4	
80	2.1	97.9	2.1	3.7	96.3	3.7	
200	1.0	98.9	1.1	1.8	98.1	1.9	
Minus 200	1.1	100.0		1.9	100.0	-	
TOTALS	100.0	-	-	100.0	-	-	
FINENESS MODULUS		-			3.4		
ORGANIC MATTER COLOUR		-			-		

K. B. Balfour, C.E.T., Supervisor
INSPECTION

WARNOCK HERSEY INTERNATIONAL LIMITED

Professional Services Division

CLIENT: Dept. of Mines, Province of N.S.

DATE: May 21, 1976

CONTRACT NO: Private

NAME OF PIT: Clients Sample Mark: Campbell's Brook #1

SOUNDNESS TEST FIVE CYCLE SODIUM SULPHATE
ASTM DESIGNATION C-88-63

SAMPLE NO. 1543	DESCRIPTION OF MATERIAL Pit Run Crushed in lab to 3/4" Max.		
Sieve Size Held On	% Loss Each Frac.	Original Grading Percent	Percent Loss Weighted on Original Grading
Coarse Aggregate			
1"			
3/4"	(5.6)	9.4	0.5
1/2"		43.5	
3/8"	5.6	19.5	3.6
No. 4	2.8	27.6	0.8
TOTALS	8.4	100.0	4.9

Passes Dept. of Highways, Nova Scotia requirement of 10% maximum loss for Hot Mix Asphalt, type B.

Warnock Hersey Professional Services Ltd.

File 514-0000 PETROGRAPHIC ANALYSIS

CONTRACT NO. PRIVATE LABORATORY NO. 1543 DATE May 21, 1976

DESCRIPTION OF SAMPLE Lab Crushed to 3/4" - 3/8" MIX TYPE B

SOURCE Clients Sample Mark: Campbell Brook #1

CONTRACTOR Received via Mr. Gordon Dickie DATE SAMPLED April 20, 1976

ROCK TYPES	QUALITY (PERCENT)			
	EXCELLENT (1)	GOOD (3)	FAIR (6)	POOR (10)
QUARTZITE	2.4			
GRANITE	42.7	0.7		
VOLCANIC	43.6	3.4	2.2	
SANDSTONE		2.6	1.4	
CARBONATE		0.4	-	
SHALE			0.6	
TOTALS	88.7	7.1	4.2	

PETROGRAPHIC NUMBER FOR HOT MIX 135.2

( ) FACTOR

Appendix 3

Pottery Evaluations of the Moran Clay (Sites 55/00 and 34/02; Table 1)

1. Ezra Morrell Artsans bed and breakfast, Lunenburg.
2. CaroleMacDonald, potter, Cape Breton.
3. Vickie Salinas, potter, Nepean Ontario.
4. Marg Killey, potter, Deep River, Ontario.
5. Carolyn Gibbs, potter, North Augusta, Ontario.
6. Beryl Budnarski, potter, Hamilton, Ontario.

From: The Artisans <info@theartisans.ca>
To: <donkeybrae@ns.sympatico.ca>
Date: 2003-08-21 10:03:19 PM
Subject: Celtic Red

Dear Mary

I am sending this letter so you will have a record of my thoughts and opinion as they pertain to my experience with the earthenware clay sample (Celtic Red).
As you know I am a studio potter and graduate of the ceramics program at the Nova Scotia College of Art and Design. During my studies at NSCAD I experimented with a number of clay bodies, some local and some from as far as Kentucky. I also spent considerable time testing two different clays I mined in the Margaree Valley area. Upon receiving the sample from you I was surprised at the apparent quality but suspicious of its actual workability, kind of a "must be too good to be true," scenario. After minimal effort and no special equipment I was able to add enough water to the clay transforming it into an homogeneous and plastic body. The clay makes an excellent throwing body. The particles are fine enough to make the clay very plastic and easy to alter without tearing. The clay also holds its shape considerably well and doesn't have a greasy organic feel which can often happen with naturally occurring plastic clays. While throwing I encountered a number of small stones. This may be due to the early location from which my sample had been taken. The stones don't pose an immediate threat but do cause some annoyance. The drying shrinkage seems standard and the firing shrinkage (aprox 10%) is also standard. After the first firing I was surprised to find absolutely no scumming. Many earthenware clays contain soluble salts which cause a white scum to form on the clays after firing however this clay does not, bonus! The clay fires easily to cone 04 (1050 centigrade) and could perhaps go higher without any trouble. A few common glazes I tested fit ok however it isn't difficult to change a glaze's chemistry in order to fit a clay body properly.
All in all I found the clay body very good and really hope it becomes available to potters. Historically potteries only existed in the vicinity of natural clay deposits therefore the potters creations came directly from the ground they stood on. Now that special relationship between the potter and his or her materials has been lost. In most cases Nova Scotia potters pick up their clay in a box sent from Ontario or the U.S. If Celtic Red becomes accessible to local potters it will do a lot more for the industry than provide an excellent quality clay.

Sincerely, Ezra Morrell

ps. Lantz powdered clay is $16.00 for 50lb bag (base for mix your own, probably adds up to $20.00 per 50lbs once you add the other stuff)
Millers #20red is $32.40 per 50lb wet (ready to throw)

The Artisans Bed and Breakfast
141 Pelham St
PO Box 1927
Lunenburg, NS
B0J 2C0 Canada
phone- (902) 634-4835
toll free- 1 866 450 9010
www.theartisans.ca
info@theartisans.ca

>>> "Carole MacDonald" <gcpotter@ns.sympatico.ca> 11/13/02 04:54PM >>>
Hello Ralph:
I am quite fascinated with this CB clay and the biggest problem is that it is so unclean, it requires much effort to get it to the point of acceptable use. Having said that, I tested it this past spring against two other low-fire clays - (Millers and Tuckers) and the most important thing I noticed was that the silica did not separate in the CB clay while throwing. What I mean is, the sludge of the M and T clays had dense silica in the bottom of my water bowl - absolutely in suspension with Cape Breton clay! I suspect this is a very important attribute.
I made several sculpture pieces (highly decorative with many attachments) and without any cleaning out of stones, the clay split on drying. With some effort to remove stones, they dried well and I was also able to pick out stones as the clay dried and they came to the surface.
Throwing the clay brought out many stones which seemed invisible at the start. This made it hard on the hands! However, again when drying I picked out the stones as they came to the surface which of course, left some pits.
I made a dozen pieces which I fired to Cone 06 then glazed using my regular majolica glaze and colorants and fired to Cone 04 with excellent results.
I actually sold these pieces with the spin that the clay was from Cape Breton and the irregularities (pits from ancient stone) made them a collectors item!!!!!!!! I did keep one for posterity.

To sum up:
excellent for throwing - better than Millers (US) and Tuckers (Ontario)
excellent for glazing using glazes used on the above mentioned clay bodies
excellent for sculpture - removing the big bits
The downside:
Takes too much time to clean out the stones and these make it rather rough when throwing.

Hope this is of some use to you.
Kind regards
Carole MacDonald

NOVA SCOTIA Natural Resources

PO Box 698
Halifax, Nova Scotia
B3J 2T9

Fax: 902 424-7735

Our File Number:

Pottery Clay Questionnaire

1. Please circle sample number. 55/02 (34/02)

2. How would you rate the plasticity of this clay on a scale of 1 (poor)-10 (excellent).

1 2 3 4 5 6 7 (8) 9 10

3. Are there any deleterious impurities (ie. stones) in the clay?

(Yes)	No

4. Did the fired clay fit your favourite glaze?

(Yes)	No

Comments:

I used the clay 3 months after receiving it. It was, at that time, still easy to work with.

I used all the clay for wheel work - none for hand building so I can not comment on its suitability for slab work.

5. Please provide an overall assessment of the clay (also use the back of the sheet).

The clay had several stones (small) & air pockets and so should be screened & passed. The small stones are a problem - but I found the clay plastic & easy to throw - it tolerated very well all the various methods I used when throwing it & did not collapse when pushed to extremes of either thinness or angle. Except for the stones I enjoyed using it. I tried 6 different glazes and all fit well as 05 - but there was alot of pinholing - perhaps due to offgassing from the clay - though it was bisqued to 04?

Nova Scotia Government Web Site
http://www.gov.ns.ca

→ However there are many causes of pinholing in glazes that have nothing to do with the clay. So I do not consider this a serious clay problem - I enjoyed the clay - workable & a nice colour. Vickie Salinas, 15 Chesterton Dr., Nepean, ON. K2E 5T1 Vickie salinas @ rogers.com.

NOVA SCOTIA Natural Resources

PO Box 698
Halifax, Nova Scotia
B3J 2T9

Fax: 902 424-7735

Our File Number:

Pottery Clay Questionnaire

1. Please circle sample number. 55/02 34/02 FROM FUSION

2. How would you rate the plasticity of this clay on a scale of 1 (poor)-10 (excellent).

1 2 3 4 5 6 7 (8) 9 10

3. Are there any deleterious impurities (ie. stones) in the clay?

(Yes) JUST A FEW	No

4. Did the fired clay fit your favourite glaze? NOT GLAZED - STAINED, TERRA SIG

(Yes)	No

Comments: I AM A HAND BUILDER, USING SMALL SLABS + COILS PRIMARILY. PLASTICITY WAS A LITTLE LOW, BUT WOULD BE MORE OF A PROBLEM IF IT WAS BEING THROWN.

5. Please provide an overall assessment of the clay (also use the back of the sheet).

CONSIDERING THE ABSENCE OF PROCESSING THIS WAS AN EXCELLENT CLAY TO WORK WITH. I AM INCLUDING THE SMALL IMPURITIES WHICH I FOUND. THE COLOUR IS WHAT I LOOK FOR IN EARTHENWARE.

I WOULD BE INTERESTED IN KNOWING IF AND WHERE THIS CLAY CAN BE PURCHASED.

Nova Scotia Government Web Site
http://www.gov.ns.ca

MARG KILLEY
P.O Box 846
DEEP RIVER, ON
K0J 1P0

killey@magma.ca

Printed on paper that contains recycled fibre.

NOVA SCOTIA Natural Resources

PO Box 698
Halifax, Nova Scotia
B3J 2T9

Fax: 902 424-7735

Our File Number:

Pottery Clay Questionnaire

1. Please circle sample number. (55/02) 34/02

2. How would you rate the plasticity of this clay on a scale of 1 (poor)-10 (excellent).

1 2 3 4 5 6 7 8 9 (10)

3. Are there any deleterious impurities (ie. stones) in the clay?

(Yes) | No

4. Did the fired clay fit your favourite glaze?

(Yes) | No

Comments:

The only problem I encountered was the small impurities cracked the plate in the ghost firing ∆04.

5. Please provide an overall assessment of the clay (also use the back of the sheet).

An easy throwable clay, good colour and a tooth which makes for easy handling.
A very good clay for children & beginners

Thank-you for the opportunity to test your clay & read your abstracts. It was great fun. Dy.

Nova Scotia Government Web Site
http://www.gov.ns.ca

NOVA SCOTIA Natural Resources

PO Box 698
Halifax, Nova Scotia
B3J 2T9

Fax: 902 424-7735

Our File Number:

Pottery Clay Questionnaire

1. Please circle sample number. 55/02 (34/02)

2. How would you rate the plasticity of this clay on a scale of 1 (poor)-10 (excellent).

1 2 3 4 5 6 7 8 9 (10)

3. Are there any deleterious impurities (ie. stones) in the clay?

(Yes)	No

A FEW VERY TINY PIECES, FROM SPECS. TO APPROX. 0

4. Did the fired clay fit your favourite glaze?

(Yes)	No

Comments:

FIRED ONCE TO 1206 WAS PERFECT
- THE ODD TINY PINHOLE

5. Please provide an overall assessment of the clay (also use the back of the sheet).

THE CLAY FELT WONDERFUL. I USUALLY USE A COMMERCIAL WHITE EARTHENWARE + OCCASIONALLY RED. IT BURNISHES LIKE A DREAM, USING ONLY FINGERS.

Beryl Budreck

Printed on paper that contains recycled fibre

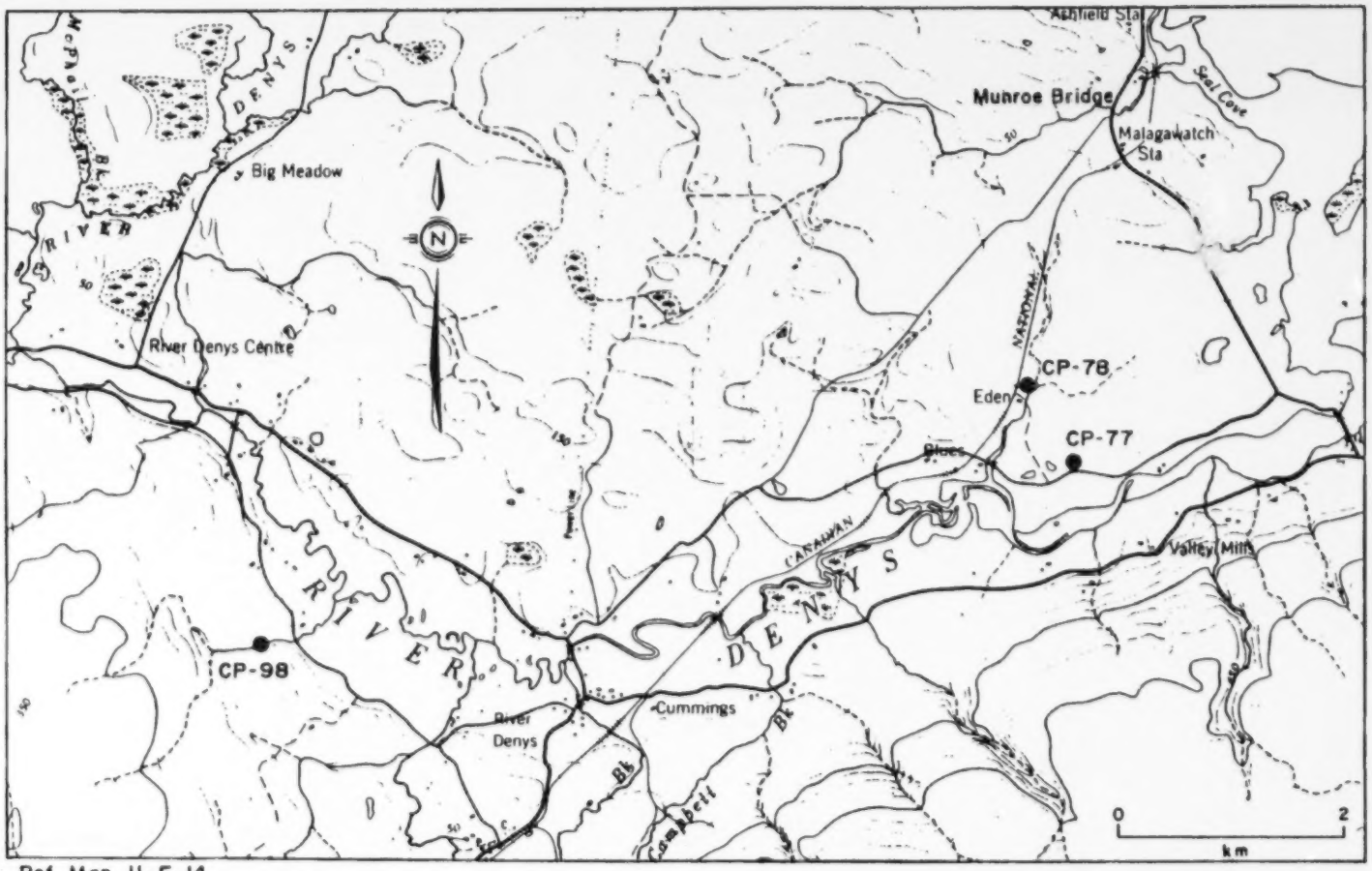
Appendix 4

Clay Analyses from the Eden Deposit, River Denys Lowlands (after Gouthro, 1989)

Includes:

1. Sample location map.

2. Sample descriptions and firing tests.



Ref. Map 11-F-14

Figure 48. Location map for samples CP-77, 78, 98 (River Denys, Cape Breton Island)

INVERNESS COUNTY

Sample Number
CP-77

TOPOGRAPHICAL SHEET: 11F/14

LOCATION: Approximately 750 m east of Blues, and 800 m southeast of Eden (Fig. 48).

UTM: 645980 E
5078980 N

GEOLOGICAL UNIT: Pleistocene clay, Quaternary age

DESCRIPTION: Light grey clay, 15 cm thick. The clay contains organic matter and exhibits iron carbonate stains. Underlying this is a reddish-brown clay which has a thickness in excess of 61 cm.

SAMPLE INTERVAL: Channel sample across the upper 30 cm of thickness.

TYPE OF MATERIAL: Clay

UNFIRED CHARACTERISTICS: Pale reddish-brown, noncalcareous clay. Very good workability. Highly plastic. Water of plasticity 26.8%. Safe drying. Air shrinkage 7.2%. Modulus of rupture 395 p.s.i. Benzidine test negative.

P.C.E.: 3+

FIRED CHARACTERISTICS:

Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness
06	7.25	3.30	Moderate reddish brown	Steel hard
04	7.85	0.79	Dark reddish brown	Steel hard
02	0.90	0.49	Dark reddish brown	Steel hard

POTENTIAL USES: Earthenware, artware and structural products

INVERNESS COUNTY

Sample Number
CP-78

TOPOGRAPHICAL SHEET: 11F/14

LOCATION: Eden, on the property of Mr. Walter Miller. The clay was exposed by digging in a field east of Mr. Miller's house (Fig. 48).

UTM: 645580 E
5079680 N

GEOLOGICAL UNIT: Clay, Quaternary age

DESCRIPTION: Reddish-brown clay containing carbonaceous and organic material. The clay has a thickness in excess of 61 cm.

SAMPLE INTERVAL: Channel sample across top 30 cm of thickness

TYPE OF MATERIAL: Clay

UNFIRED CHARACTERISTICS: Pale reddish-brown, highly calcareous clay. Very good workability. Highly plastic. Water of plasticity 28.0%. Safe drying. Air shrinkage 8.1%. Modulus of rupture 383 p.s.i. Benzidine test negative.

P.C.E.: 3+

FIRED CHARACTERISTICS:

Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness
06	1.70	12.92	Moderate reddish orange	Very hard
04	2.20	11.66	Moderate reddish orange	Very hard
02	6.90	0.09	Dark reddish brown	Steel hard

POTENTIAL USES: Artware and brick.

Appendix 5

Groundwater Report of the Kingsville Drillhole (KV-01-2)

424-0501

Lynn
92 Crestdale Drive
Sydney Forks
Cape Breton County
B1L 1A1

January 20, 2002

Mary Feetham
c/o Ralph Stea
Nova Scotia Department of Natural Resources
PO Box 698
Halifax, Nova Scotia
B3J 2T9

Dear Mary,

Enclosed please find the original water chemistry from the overflowing well in Kingsville.

For your records the following summarizes a brief assessment of the groundwater conditions encountered in the test hole (KV). Test drilling was carried out by Landtec, using a CME equipped with a hollow stem auger. My notes indicate drilling proceeded through uniform red clay to a depth of 83 feet where a coarse gravel layer was encountered. The gravel unit continued to a total depth of 95 feet. Upon intersection of the gravel, flowing conditions occurred at the well head. There is no estimate of the flow rate from this confined unit.

Requesting an assessment of the "aquifer" at this depth, I was invited to make a site visit. By the time I arrived (November 15, 2001), the hole was finished to a depth of 290 feet, casing had been driven to a depth of 117 feet, the hole was no longer flowing, and the drillers were retrieving the rods from the hole. It was reported the hole was terminated in a grey shale, presumably in the Windsor Formation.

Within several minutes of the rod retrieval, the test hole started to overflow again. The water was clear with flecks of oxidized iron. The field conductivity was measured with a YSI conductivity meter at 2353 umhos/cm. At this time it is not know whether the flowing water was combined with drilling water and/or additives or not. A sample was collected, with intentions of submitting it to the laboratory for analysis. Within 15 minutes, the overflow became turbid (red clay). There was no visible change in flow rate. Another conductivity measurement (6200, uhmos/cm) indicated this was very different water from the preceding water. At this time another sample was collected, the suspended sediment was filtered from the sample, and it was submitted to Philip Analytical for a chemical analysis plus metal scan, iodide and bromide.

Using a graduated bucket and a stop watch, the overflow rate was measured at 1.5 igpm. Calculations based on borehole diameter, and time since drilling was terminated, indicate this was from the bottom of the hole, not the gravel aquifer encountered at 80 feet.

The water can be described as a sodium chloride type water, high in TDS and unacceptably hard. The water is salty and is not potable. There is very little other mineral dissolution impacting this water chemistry. No iodide was detected in the sample. The bromide concentration was reported to be 0.02 mg/L.

The ionic concentrations and ratios have been compared to ionic concentrations and ratios in sea water and other "salty" waters associated with the Windsor Formation around the Bras d'Or Lakes. The sample was plotted on a trilinear diagram for comparison with sea water and other Windsor "salts" water. The dissolved salt in this sample is basically sodium chloride (halite), very similar to the road salt sample I have been using for comparison (unfortunately, I do not recall where the road salt chemistry originated). The water is unusual when compared to other water chemistries I have seen in the Windsor formation, in that the percentage of sodium and chloride compared to the other cations and anions is very high. There is however, a small but measurable contribution of gypsum and magnesium salt dissolution contributing to the water chemistry.

Based on the chemistry, I expect the salt source is near by, or the water has been transmitted a long distance with very little alteration along a fault zone.

I hope this assessment will be of use to your project. A hydrogeologic/hydrogeochemical component to this project would have complimented some of the structural work you were doing. Sometimes fault lines can be confirmed using water chemistry, even collection of field conductivities are valuable in a reconnaissance survey.

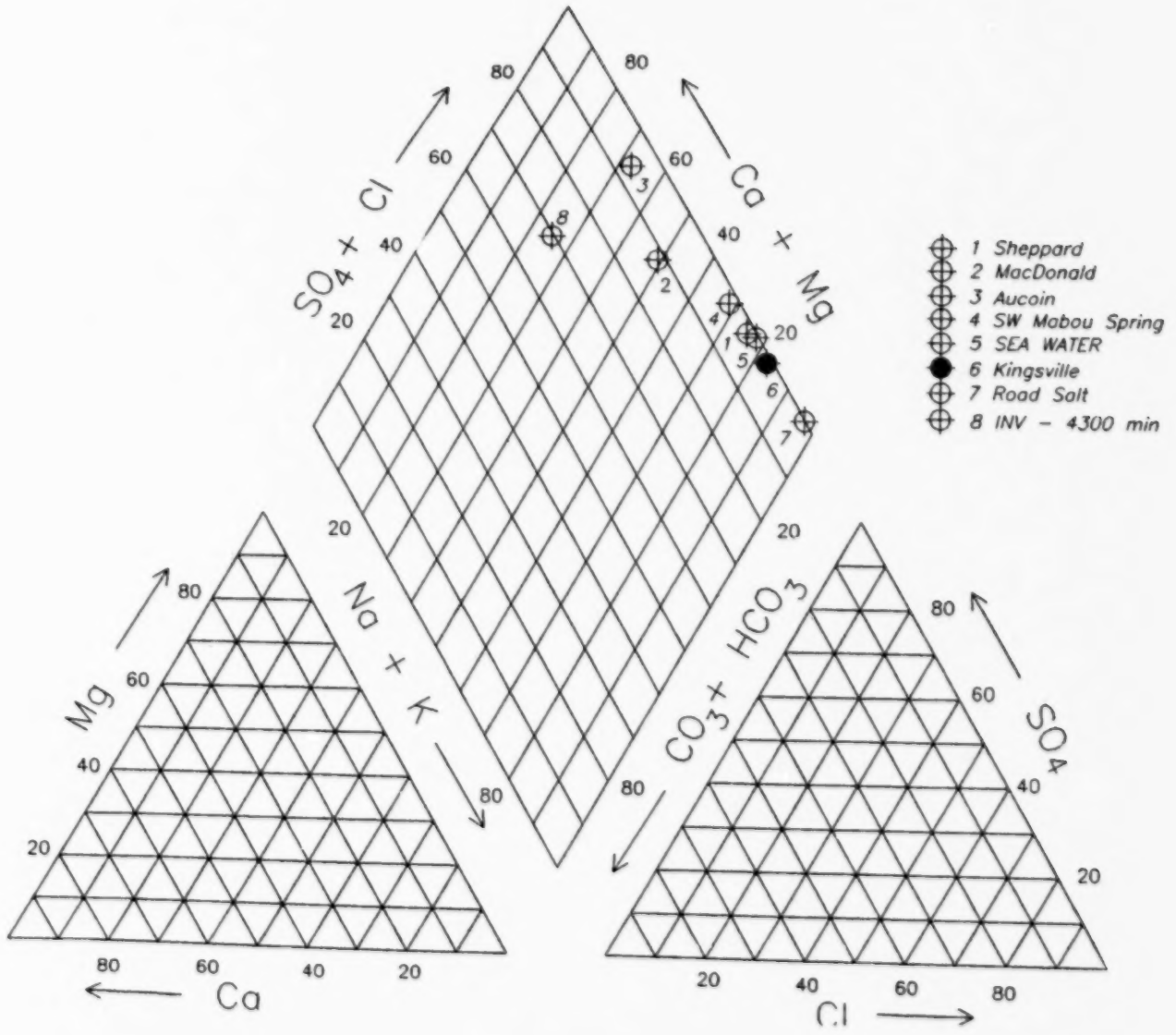
When you get the coordinates on this well could you please send them along for my records. Sorry this has taken so long, unfortunately, it kept slipping backwards on my priority list!

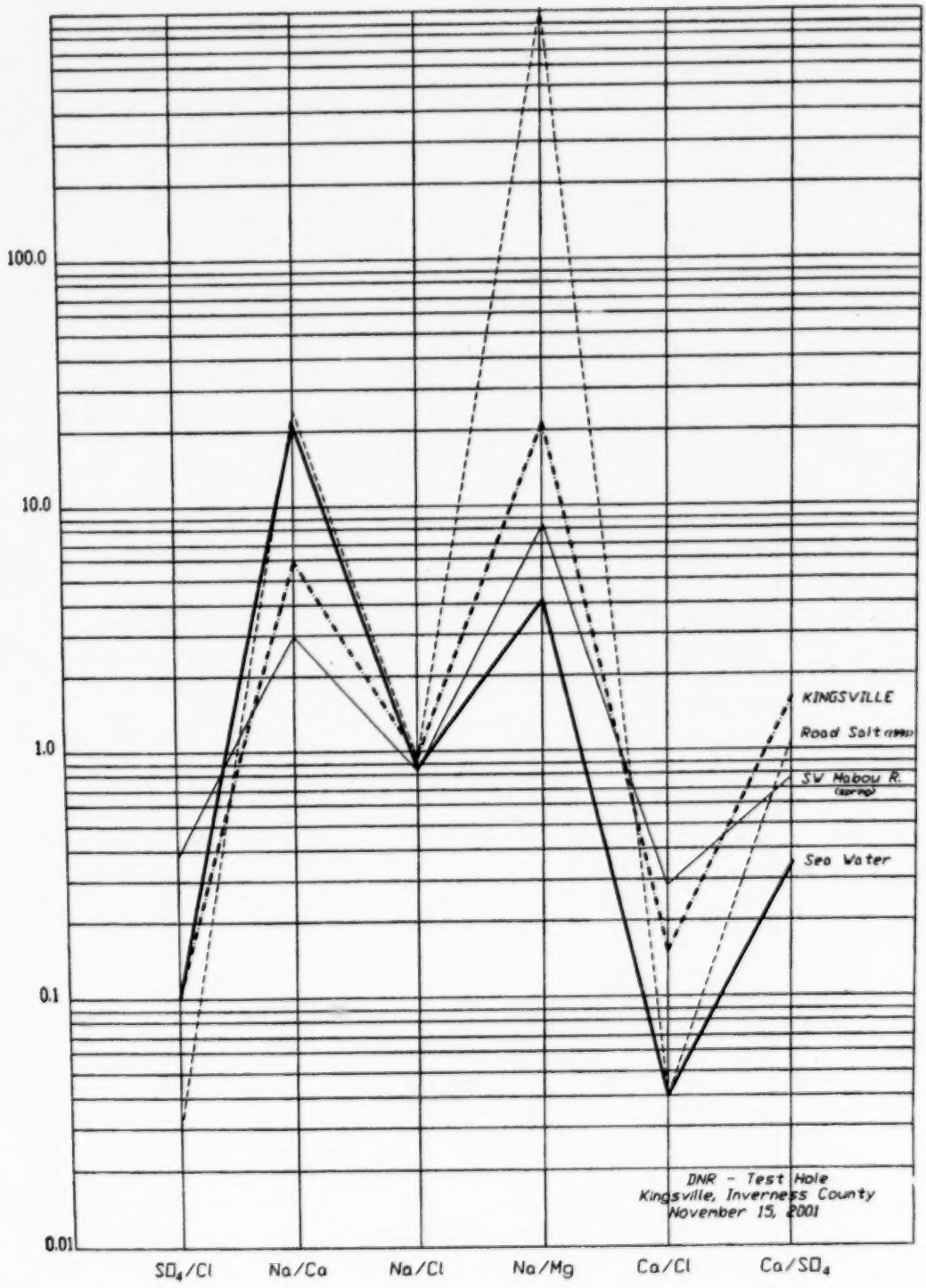
If I can be of any further assistance please do not hesitate to contact me at 564-9303 or by e-mail at:baechler@ns.sympatico.ca

Yours very truly,

Lynn Baechler, M.Sc.
Hydrogeologist

PS: Has Ralph found out anything on the drill hole coal cobbles I brought in from Inverness/Strathlorne?


SO4 + Cl
Ca + Mg
Na + K
Mg
Ca
CO3 + HCO3
SO4
Cl
80
60
40
20
1 Sheppard
2 MacDonald
3 Aucoin
4 SW Mabou Spring
5 SEA WATER
6 Kingsville
7 Road Salt
8 INV – 4300 min


100.0
10.0
1.0
0.1
0.01
KINGSVILLE
Road Salt
SW Mabou R.
Sea Water
DNR - Test Hole
Kingsville, Inverness County
November 15, 2001
SO4/Cl
Na/Ca
Na/Cl
Na/Mg
Ca/Cl
Ca/SO4

Philip Analytical Services

Sample : 01-H075142
Client ID : KV-01-2
Project : Kingsville
PO# : 4102957011
Quote # : SO-L1-10

RCAp Analytes	Value	Units	meq/L	Method
Sodium	1260	mg/L	54.8	ICP-OES
Potassium	4.2	mg/L	0.11	ICP-OES
Calcium	187.	mg/L	9.33	ICP-OES
Magnesium	31.4	mg/L	2.58	ICP-OES
Alkalinity (as CaCO3)	24.	mg/L	0.48	COBAS
Sulfate	269.	mg/L	5.60	COBAS
Chloride	2050	mg/L	57.8	COBAS
Reactive Silica (as SiO2)	4.2	mg/L		COBAS
Ortho Phosphate (as P)	0.01	mg/L		COBAS
Nitrate + Nitrite (as N)	< 0.05	mg/L		COBAS
Nitrate (as N)	< 0.05	mg/L		COBAS
Ammonia (as N)	0.13	mg/L	0.01	COBAS
Iron	< 0.02	mg/L		ICP-OES
Manganese	0.23	mg/L		ICP-OES
Copper	< 0.01	mg/L		ICP-OES
Zinc	0.17	mg/L	0.01	ICP-OES
Color	10.	TCU		COBAS
Turbidity	0.1	NTU		NEPH.
Conductance (RCAp)	7750	uS/cm		Electrode
pH	7.3	Units		Electrode
RCAp Computed Analytes				
Hardness (as CaCO3)	596.	mg/L		Calculated
Bicarbonate (as CaCO3)	24.	mg/L	0.48	Calculated
Carbonate (as CaCO3)	< 1	mg/L		Calculated
TDS (Calculated)	3820	mg/L		Calculated
Theoretical Conductance	8120	umho/cm		Calculated
RCAp Computed Indexes				
Cation Sum	66.8	meq/L		Calculated
Anion Sum	63.9	meq/L		Calculated
Ion Balance	2.26	%		Calculated
Langelier Index (5 C)	-1.06			Calculated
Saturation pH	8.36	Units		Calculated

Report To:
BAECHLER, LYNN
ADI Limited
P.O. Box 1688
Sydney, NS, B1P 6R7
902-564-5660

Date Received: Nov 16, 2001
Date Reported: Dec 4, 2001

Inorganics Manager
Jerry Arenovich

Philip Analytical Services

Sample : 01-H075142
Client ID : KV-01-2
Project : Kingsville
PO# : 4102957011
Quote # : SO-L1-10

RCAp MS Analytes	Value	Units	EQL	Method
Phosphorus	< 0.1	mg/L	0.1	ICP-OES
Nitrite	< 0.01	mg/L	0.01	COBAS
Iron	< 0.2	mg/L	0.02	ICP-MS
Manganese	0.22	mg/L	0.002	ICP-MS
Copper	< 0.02	mg/L	0.002	ICP-MS
Zinc	< 0.02	mg/L	0.002	ICP-MS
Total Org. Carbon (by UV)	3.1	mg/L	0.5	U.V.-ox
RCAp MS Computed Indexes				
Langlier Index @ 4C	-1.08			Calculated
Langlier Index @ 20C	-0.68			Calculated
Saturation pH @ 4C	8.38	Units		Calculated
Saturation pH @ 20C	7.98	Units		Calculated

Report To:
BAECHLER, LYNN
ADI Limited
P.O. Box 1688
Sydney, NS, B1P 6R7
902-564-5660

Date Received: Nov 16, 2001
Date Reported: Dec 4, 2001

Inorganics Manager JK
Jerry Arenovich

Philip Analytical Services

Sample : 01-H075142
Client ID : KV-01-2
Project : Kingsville
PO# : 4102957011
Quote # : SO-L1-10

Inorganic Analytes	Value	Units	EQL	Method
Inorganic Comment	Comment		Pending	
Aluminum	< 0.1	mg/L	0.01	ICP-MS
Antimony	< 0.02	mg/L	0.002	ICP-MS
Arsenic	< 0.02	mg/L	0.002	ICP-MS
Barium	< 0.05	mg/L	0.005	ICP-MS
Beryllium	< 0.05	mg/L	0.005	ICP-MS
Bismuth	< 0.02	mg/L	0.002	ICP-MS
Boron	0.055	mg/L	0.005	ICP-MS
Cadmium	< 0.003	mg/L	0.0003	ICP-MS
Chromium	< 0.02	mg/L	0.002	ICP-MS
Cobalt	< 0.01	mg/L	0.001	ICP-MS
Lead	< 0.005	mg/L	0.0005	ICP-MS
Molybdenum	0.020	mg/L	0.002	ICP-MS
Nickel	< 0.02	mg/L	0.002	ICP-MS
Selenium	< 0.02	mg/L	0.002	ICP-MS
Silver	< 0.005	mg/L	0.0005	ICP-MS
Strontium	2.4	mg/L	0.005	ICP-MS
Thallium	< 0.001	mg/L	0.0001	ICP-MS
Tin	< 0.02	mg/L	0.002	ICP-MS
Titanium	< 0.02	mg/L	0.002	ICP-MS
Uranium	< 0.001	mg/L	0.0001	ICP-MS
Vanadium	< 0.02	mg/L	0.002	ICP-MS
Bromide	0.02	mg/L	0.02	ICP-MS
Filtration	By Client		Pending	0.45 um

Comments: Please find the PSC Burlington report attached for iodide results.

Report To:
BAECHLER, LYNN
ADI Limited
P.O. Box 1688
Sydney, NS, B1P 6R7
902-564-5660

Date Received: Nov 16, 2001
Date Reported: Dec 4, 2001

Inorganics Manager
Jerry Arenovich

Appendix 6

Recommendations for the Evaluation of the Resource Potential of Recently Discovered Clay Deposits in Cape Breton Island

prepared by

R. R. Stea, R. J. Ryan, M. Feetham and P. Finck
Mineral Resources Branch
Department of Natural Resources

for

Nova Scotia Office of Economic Development
Strait-Highlands Regional Development Agency

May 2002

Introduction

Deposits of clay have recently been discovered in southwestern Cape Breton Island by staff of the Nova Scotia Department of Natural Resources (Stea *et al.*, 2002). These abundant, surface clay deposits occur in lowland areas and were deposited in large glacial lakes formed at the end of the last glaciation when glaciers dammed rivers flowing into the Gulf of St. Lawrence (Fig. 1). The deposits were discovered during the course of Quaternary mapping done as part of a collaborative project between the Nova Scotia Department of Natural Resources and Natural Resources Canada, with funding support from the federal government's Targeted Geoscience Initiative.

Preliminary mapping and sampling of the clays indicate that they are widespread, fine-grained and homogenous. Clays used for ceramics and structural products have a wide range of physical and thermal reactivity property requirements, with each particular industrial product using a specific clay. A common denominator for the development of any clay resource is that it comprise a large-volume of moderately uniform clay that has a low shrinkage/swelling percentage, consistent firing colour, and a good strength after firing. Limited preliminary testing indicates that the Cape Breton Island clays meet these requirements.

It is important to remember that the Cape Breton clay deposits are not regulated by the Mineral Resources Act of Nova Scotia and that their ownership resides with the landowner. The following suggestions are being provided for consideration by economic development agencies in the development of a strategic plan to assess the economic viability of an industrial clay industry in southwestern Cape Breton Island.

Recommendations

The Mineral Resources Branch recommends that the economic evaluation of clays in southwestern Cape Breton Island be done in a three component program: (a) evaluation of the potential for a small scale, pottery industry, (b) evaluation of the potential for a large scale, industrial clay products industry and (c) a market analysis study. These components, with estimated costs, are outlined below.

Component A. Evaluation of the Potential of Individual Clay Deposits for a Small-scale Pottery Clay Industry

Limited tests of the clay deposits in the Moran basin (Fig. 1) near Glencoe indicate that they are suitable for use as pottery clays (Stea *et al.*, 2002). Although marketing of pottery clays might ultimately be only a very small part of an industrial development centred on the clay resources, it will probably be the first development of the deposits. A local entrepreneur, Blaise Moran, who currently produces aggregate from a property that he owns in the area, has expressed interest in supplying clay from that property for pottery. Preliminary mapping and testing indicate that there is suitable clay on his property. This may also be the case for other landowners in the area and, therefore, we recommend that expressions of interest from private land holders be addressed with the following protocol.

1. NSDNR will follow its normal practices in publishing and disseminating information on the clay resource potential in southwestern Cape Breton Island, which results from the regional mapping, geophysical surveys, trenching and drilling being done as part of the Targeted Geoscience Initiative project. These practices include oral and poster presentations at workshops and conferences, and a variety of departmental reports and publications. All of these are publicly available. For example, results for the pottery clays in the Moran basin were presented at the annual Mining Matters conference in November 2001, and at the Glencoe Clay Workshop in February 2002. These results will also be published in NSDNR's Report of Activities for 2001 and posted on the Mineral Resources Branch website.

2. NSDNR staff will provide geological information and advice to individuals on request.
3. NSDNR staff will advise interested individuals on appropriate steps to be followed for evaluation of clay resources on private lands, which might require hand-dug pits, hand-auger surveys, backhoe trenching or the use larger drill rigs to define the distribution of clay and to obtain samples for characterization of the physical and chemical properties of the clay. NSDNR staff will also advise interested individuals of qualified geological consultants available to complete a resource evaluation.
4. NSDNR staff will be available to offer scientific opinions on the geology of any clay deposits that are exposed or excavated during the evaluation period (dependent on staff availability).
5. NSDNR staff will recommend testing methodologies to determine the characteristics of a deposit, where applicable.

Cost: The NSDNR activities in this component are part of normal program operations and have no incremental cost. Private landowners might approach economic development agencies for financial assistance in evaluating the potential of their lands to contain economically feasible clay deposits.

Component B. Evaluation of the Potential of Southeastern Cape Breton Island to Support a Large-scale Industrial Clay Products Industry

This component will evaluate the potential of southeastern Cape Breton Island to support high volume production of clay for structural products such as bricks, roofing and floor tile, drain tile and sewer pipe. Emphasis will be placed on Crown land in order to provide the best opportunity for development without becoming involved in complexities related to clay deposits on private land. This component comprises three phases: (1) regional geological mapping and sampling, (2) detailed exploration and testing of deposits in basins identified from the regional program as most promising, and (3) external review.

Phase 1: Regional Geological Mapping and Sampling

Much of the regional mapping and sampling required for this phase are part of normal program operations and have no incremental cost. Analytical methods to obtain data on the deposits will have associated costs.

Cost: The estimated cost of the sampling and analytical program is $20,000.

Phase 2: Detailed Exploration in Promising Basins

The regional mapping and sampling program (Phase 1) being done as part of the TGI project will identify areas with the potential to contain significant clay resources. The next step in evaluating these potential areas is detailed exploration to determine the location, size and properties of clay deposits within them. Such detailed exploration is outside the mandate of NSDNR, and is the responsibility of the private sector. NSDNR recommends that a contract geologist with suitable experience be employed for this phase of the resource evaluation if economic development agencies decide that it should be done. NSDNR can provide assistance and supervision for the contract work, subject to staff availability.

Phase 2 will require approximately six months to complete and will comprise:
1. Hand- and/or gas-powered auger drilling to obtain samples from the prospective sites, carried out on a grid pattern with spacing of 1 sample each 100 metres.
2. Follow-up work to obtain more information and samples from clay deposits discovered during the auger drilling. This work could involve use of a back hoe to dig trenches, or the use of a truck-mounted auger.

3. Testing and analysis of samples.
4. Preparation of a report describing the locations, estimated volumes and tonnages, and ceramic properties of the clay deposits.

Cost: The estimated costs of this phase include:

Salary (contract geologist) $30,000
Auger drilling $20,000
Trenching $5,000
Testing and analysis $20,000
Total $75,000

Phase 3: External Review

A review and evaluation of the results of Phase 2 should be obtained through a contract with an independent industrial minerals geologist with expertise in clays. This review will validate the results of testing and evaluation and provide information that is essential to Component C.

Cost: The estimated cost of this phase is:
Contract $10,000

Component C. Market Analysis Study

A comprehensive study of the potential for a Nova Scotia-based industrial clay products industry to penetrate national and international markets should be undertaken in concert with phases 2 and 3 of Component B. This study requires economic and business expertise that is not part of NSDNR. It might best be done under the leadership of the Department of Economic Development, with input on resource quality and quantity from NSDNR. The market study is essential to decisions about development of any clay deposit discovered and explored in the other components, and will require that information from the other components be made available to the market study as quickly as possible.

Cost: NSDNR is uncertain of the costs of engaging a consultant to carry out a market analysis. Our limited experience suggests that $20,000 may be an appropriate cost.

Reference

Stea, R. R., M. Feetham, S. E. Pullan and W. Ostrom 2002: Deposits of Earhtenware Clay in Southwestern Cape Breton Island; *in* Minerals and Energy Branch, Report of Activities 2001; Nova Scotia Department of Natural Resources, Report ME 2002-1, p. 113-128.

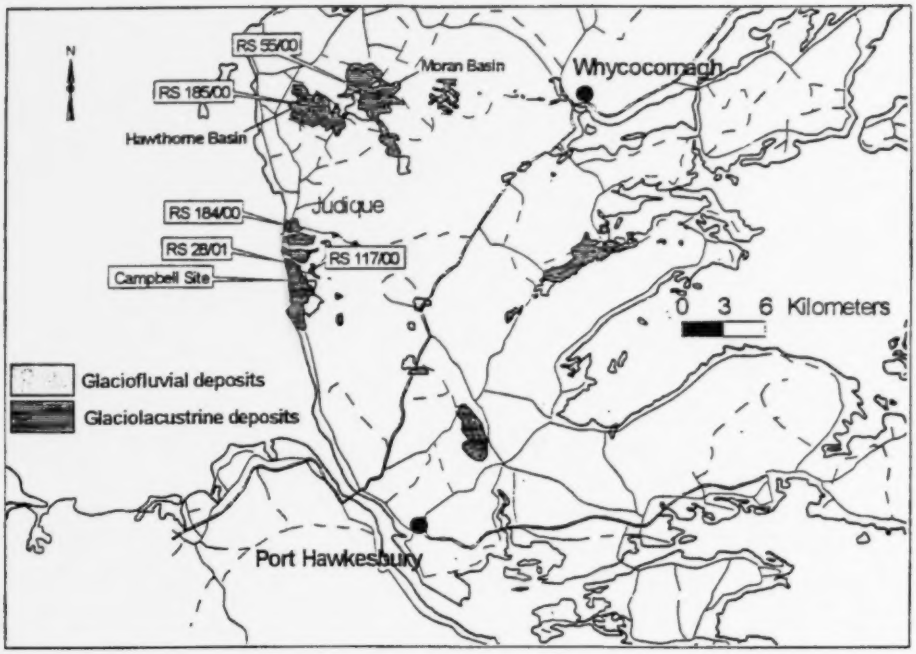


Fig. 1 Clay basins in Southwest Cape Breton

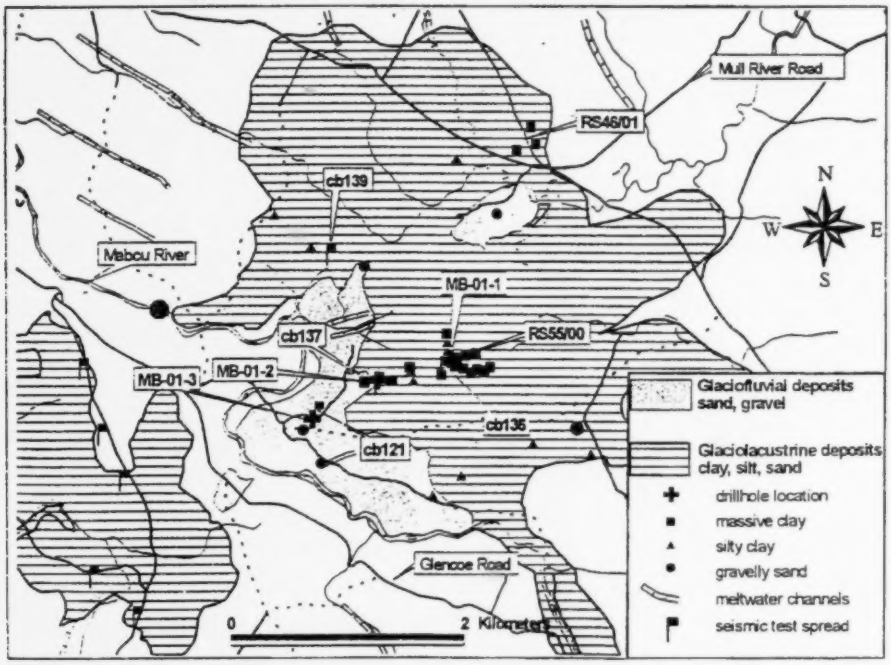


Fig. 2. Close up of the Moran Basin near Glencoe and locations of samples.